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Entry, Descent, and Landing: 2000-2004

This custom bibliography from the NASA Scientific and Technical Information Program lists a sampling of records found in the NASA Aeronautics and Space Database. The scope of this topic includes technologies for precision targeting and landing on “high-g” and “low-g” planetary bodies. This area of focus is one of the enabling technologies as defined by NASA’s *Report of the President’s Commission on Implementation of United States Space Exploration Policy*, published in June 2004.

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A Custom Bibliography From the
NASA Scientific and Technical Information Program

October 2004

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This custom bibliography from the NASA Scientific and Technical Information Program lists a sampling of records found in the NASA Aeronautics and Space Database. The scope of this topic includes technologies for precision targeting and landing on ″high-g″ and ″low-g″ planetary bodies. This area of focus is one of the enabling technologies as defined by NASA's *Report of the President's Commission on Implementation of United States Space Exploration Policy*, published in June 2004.

OCTOBER 2004

20040120953 Computer Sciences Corp., Huntsville, AL, USA
Atmospheric Models for Aerocapture Systems Studies
Justus, C. G.; Duvall, Aleta; Keller, Vernon W.; December 19, 2003; In English, 16-19 Aug. 2004, Providence, RI, USA
Contract(s)/Grant(s): NAS8-60000; No Copyright; Avail: Other Sources

Aerocapture uses atmospheric drag to decelerate into captured orbit from interplanetary transfer orbit. This includes capture into Earth orbit from, for example, Lunar-return or Mars-return orbit. Eight Solar System destinations have sufficient atmosphere for aerocapture to be applicable - three of the rocky planets (Venus, Earth, and Mars), four gas giants (Jupiter, Saturn, Uranus, and Neptune), and Saturn's moon Titan. These destinations fall into two groups: (1) The rocky planets, which have warm surface temperatures (approx. 200 to 750 K) and rapid decrease of density with altitude, and (2) the gas giants and Titan, which have cold temperatures (approx. 70 to 170 K) at the surface or 1-bar pressure level, and slow rate of decrease of density with altitude. The height variation of average density with altitude above 1-bar pressure level for the gas giant planets is shown. The periapsis density required for aerocapture of spacecraft having typical values of ballistic coefficient (a measure of mass per unit cross-sectional area) is also shown. The aerocapture altitudes at the gas giants would typically range from approx. 150 to 300 km. Density profiles are compared for the rocky planets with those for Titan and Neptune. Aerocapture at the rocky planets would occur at heights of approx. 50 to 100 km. For comparison, typical density and altitudes for aerobraking operations (circularizing a highly elliptical capture orbit, using multiple atmospheric passes) are also indicated.
Author (revised)
Atmospheric Models; Aerocapture; Aerobraking; Planetary Atmospheres

20040120944 NASA Langley Research Center, Hampton, VA, USA
Preliminary Convective-Radiative Heating Environments for a Neptune Aerocapture Mission
Hollis, Brian R.; Wright, Michael J.; Olejniczak, Joseph; Takashima, Naruhisa; Sutton, Kenneth; Prabhu, Dinesh; [2004]; In English; AIAA Atmospheric Flight Mechanics Conference and Exhibit, 16-19 Aug. 2004, Providence, RI, USA
Contract(s)/Grant(s): NAS2-99092; NAS1-00135; NCC1-02043; 320-10-00
Report No.(s): AIAA Paper 2004-5177; No Copyright; Avail: CASI; A03, Hardcopy

Convective and radiative heating environments have been computed for a three-dimensional ellipsled configuration which would perform an aerocapture maneuver at Neptune. This work was performed as part of a one-year Neptune aerocapture spacecraft systems study that also included analyses of trajectories, atmospheric modeling, aerodynamics, structural design, and other disciplines. Complementary heating analyses were conducted by separate teams using independent sets of aerothermodynamic modeling tools (i.e. Navier-Stokes and radiation transport codes). Environments were generated for a large 5.50 m length ellipsled and a small 2.88 m length ellipsled. Radiative heating was found to contribute up to 80% of the total heating rate at the ellipsled nose depending on the trajectory point. Good agreement between convective heating predictions from the two Navier-Stokes solvers was obtained. However, the radiation analysis revealed several uncertainties in the computational models employed in both sets of codes, as well as large differences between the predicted radiative heating rates.
Author
Aerocapture; Convective Heat Transfer; Radiative Heat Transfer; Neptune Atmosphere; Aerothermodynamics

20040120869 Morgan Research Corp., Huntsville, AL, USA, NASA Marshall Space Flight Center, Huntsville, AL, USA
Atmospheric Models for Aeroentry and Aeroassist
Justus, C. G.; Duvall, Aleta; Keller, Vernon W.; June 15, 2004; In English, 23-26 Aug. 2004, Moffett Field, CA, USA; Original contains color illustrations
Contract(s)/Grant(s): NNM04AA02C; No Copyright; Avail: CASI; A02, Hardcopy

Eight destinations in the Solar System have sufficient atmosphere for aeroentry, aeroassist, or aerobraking/aerocapture: Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune, plus Saturn's moon Titan. Engineering-level atmospheric models for Earth, Mars, Titan, and Neptune have been developed for use in NASA s systems analysis studies of aerocapture applications. Development has begun on a similar atmospheric model for Venus. An important capability of these models is simulation of quasi-random perturbations for Monte Carlo analyses in developing guidance, navigation and control algorithms, and for thermal systems design. Characteristics of these atmospheric models are compared, and example applications for aerocapture are presented. Recent Titan atmospheric model updates are discussed, in anticipation of applications for trajectory and atmospheric reconstruct of Huygens Probe entry at Titan. Recent and planned updates to the Mars atmospheric model, in support of future Mars aerocapture systems analysis studies, are also presented.
Author
Atmospheric Models; Solar System; Aeroassist; Aerobraking; Aerocapture; Guidance (Motion)

20040111219 NASA Langley Research Center, Hampton, VA, USA
Structural Design for a Neptune Aerocapture Mission
Dyke, R. Eric; Hrinda, Glenn A.; [2004]; In English, 16-19 Aug. 2004, Providence, RI, USA
Contract(s)/Grant(s): 23-800-90-40
Report No.(s): AIAA Paper 2004-5179; No Copyright; Avail: CASI; A03, Hardcopy

A multi-center study was conducted in 2003 to assess the feasibility of and technology requirements for using aerocapture to insert a scientific platform into orbit around Neptune. The aerocapture technique offers a potential method of greatly reducing orbiter mass and thus total spacecraft launch mass by minimizing the required propulsion system mass. This study involved the collaborative efforts of personnel from Langley Research Center (LaRC), Johnson Space Flight Center (JSFC), Marshall Space Flight Center (MSFC), Ames Research Center (ARC), and the Jet Propulsion Laboratory (JPL). One aspect of this effort was the structural design of the full spacecraft configuration, including the ellipsled aerocapture orbiter and the in-space solar electric propulsion (SEP) module/cruise stage. This paper will discuss the functional and structural requirements for each of these components, some of the design trades leading to the final configuration, the loading environments, and the analysis methods used to ensure structural integrity. It will also highlight the design and structural challenges faced while trying to integrate all the mission requirements. Component sizes, materials, construction methods and analytical results, including masses and natural frequencies, will be presented, showing the feasibility of the resulting design for use in a Neptune aerocapture mission. Lastly, results of a post-study structural mass optimization effort on the ellipsled will be discussed, showing potential mass savings and their influence on structural strength and stiffness
Author
Aerocapture; Neptune (Planet); Structural Design; Space Missions; Spacecraft Design

20040111218 NASA Langley Research Center, Hampton, VA, USA
Aerocapture Performance Analysis for a Neptune-Triton Exploration Mission
Starr, Brett R.; Westhelle, Carlos H.; Masciarelli, James P.; [2004]; In English, 16-19 Aug. 2004, Providence, RI, USA
Contract(s)/Grant(s): 23-800-90-50
Report No.(s): AIAA Paper 2004-4955; No Copyright; Avail: CASI; A03, Hardcopy

A systems analysis has been conducted for a Neptune-Triton Exploration Mission in which aerocapture is used to capture a spacecraft at Neptune. Aerocapture uses aerodynamic drag instead of propulsion to decelerate from the interplanetary approach trajectory to a captured orbit during a single pass through the atmosphere. After capture, propulsion is used to move the spacecraft from the initial captured orbit to the desired science orbit. A preliminary assessment identified that a spacecraft with a lift to drag ratio of 0.8 was required for aerocapture. Performance analyses of the 0.8 L/D vehicle were performed using a high fidelity flight simulation within a Monte Carlo executive to determine mission success statistics. The simulation was the Program to Optimize Simulated Trajectories (POST) modified to include Neptune specific atmospheric and planet models, spacecraft aerodynamic characteristics, and interplanetary trajectory models. To these were added autonomous guidance and pseudo flight controller models. The Monte Carlo analyses incorporated approach trajectory delivery errors, aerodynamic characteristics uncertainties, and atmospheric density variations. Monte Carlo analyses were performed for a reference set of uncertainties and sets of uncertainties modified to produce increased and reduced atmospheric variability. For the reference uncertainties, the 0.8 L/D flatbottom ellipsled vehicle achieves 100% successful capture and has a 99.87 probability of attaining the science orbit with a 360 m/s V budget for apoapsis and periapsis adjustment. Monte Carlo analyses were also performed for a guidance system that modulates both bank angle and angle of attack with the reference set of uncertainties.

An alpha and bank modulation guidance system reduces the 99.87 percentile DELTA V 173 m/s (48%) to 187 m/s for the reference set of uncertainties.
Author
Aerocapture; Neptune (Planet); Space Missions; Triton; Systems Analysis; Spacecraft Performance; Space Exploration

20040111217 NASA Langley Research Center, Hampton, VA, USA
Neptune Aerocapture Systems Analysis
Lockwood, Mary Kae; [2004]; In English, 16-19 Aug. 2004, Providence, RI, USA
Contract(s)/Grant(s): 23-800-90-10
Report No.(s): AIAA Paper 2004-4951; No Copyright; Avail: CASI; A03, Hardcopy

A Neptune Aerocapture Systems Analysis is completed to determine the feasibility, benefit and risk of an aeroshell aerocapture system for Neptune and to identify technology gaps and technology performance goals. The high fidelity systems analysis is completed by a five center NASA team and includes the following disciplines and analyses: science; mission design; aeroshell configuration screening and definition; interplanetary navigation analyses; atmosphere modeling; computational fluid dynamics for aerodynamic performance and database definition; initial stability analyses; guidance development; atmospheric flight simulation; computational fluid dynamics and radiation analyses for aeroheating environment definition; thermal protection system design, concepts and sizing; mass properties; structures; spacecraft design and packaging; and mass sensitivities. Results show that aerocapture can deliver 1.4 times more mass to Neptune orbit than an all-propulsive system for the same launch vehicle. In addition aerocapture results in a 3-4 year reduction in trip time compared to all-propulsive systems. Aerocapture is feasible and performance is adequate for the Neptune aerocapture mission. Monte Carlo simulation results show 100% successful capture for all cases including conservative assumptions on atmosphere and navigation. Enabling technologies for this mission include TPS manufacturing; and aerothermodynamic methods and validation for determining coupled 3-D convection, radiation and ablation aeroheating rates and loads, and the effects on surface recession.
Author
Aerocapture; Neptune (Planet); Systems Analysis; Technology Utilization; Aeroshells

20040095913 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
Mars Exploration Rovers Landing Dispersion Analysis
Knocke, Philip C.; Wawrzyniak, Geoffrey G.; Kennedy, Brian M.; Desai, Prasun N.; Parker, TImothy J.; Golombek, Matthew P.; Duxbury, Thomas C.; Kass, David M.; [2004]; In English
Report No.(s): AIAA Paper 2004-5093; No Copyright; Avail: CASI; A03, Hardcopy

Landing dispersion estimates for the Mars Exploration Rover missions were key elements in the site targeting process and in the evaluation of landing risk. This paper addresses the process and results of the landing dispersion analyses performed for both Spirit and Opportunity. The several contributors to landing dispersions (navigation and atmospheric uncertainties, spacecraft modeling, winds, and margins) are discussed, as are the analysis tools used. JPL's MarsLS program, a MATLAB-based landing dispersion visualization and statistical analysis tool, was used to calculate the probability of landing within hazardous areas. By convolving this with the probability of landing within flight system limits (in-spec landing) for each hazard area, a single overall measure of landing risk was calculated for each landing ellipse. In-spec probability contours were also generated, allowing a more synoptic view of site risks, illustrating the sensitivity to changes in landing location, and quantifying the possible consequences of anomalies such as incomplete maneuvers. Data and products required to support these analyses are described, including the landing footprints calculated by NASA Langley's POST program and JPL's AEPL program, cartographically registered base maps and hazard maps, and flight system estimates of in-spec landing probabilities for each hazard terrain type. Various factors encountered during operations, including evolving navigation estimates and changing atmospheric models, are discussed and final landing points are compared with approach estimates.
Author
Mars Exploration; Landing Modules; Roving Vehicles; Statistical Analysis; Land

20040095912 NASA Langley Research Center, Hampton, VA, USA, Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, USA
Mars Exploration Rovers Entry, Descent, and Landing Trajectory Analysis
Desai, Prasun N.; Knocke, Philip C.; August 11, 2004; In English, 16-19 Aug. 2004, Providence, RI, USA
Contract(s)/Grant(s): 23-749-30-00
Report No.(s): AIAA Paper 2004-5092; No Copyright; Avail: CASI; A02, Hardcopy

The Mars Exploration Rover mission successfully landed two rovers ‘Spirit’ and ‘Opportunity’ on Mars on January 4th and 25th of 2004, respectively. The trajectory analysis performed to define the entry, descent, and landing (EDL) scenario is described. The entry requirements and constraints are presented, as well as uncertainties used in a Monte Carlo dispersion analysis to statistically assess the robustness of the entry design to off-nominal conditions. In the analysis, six-degree-of-freedom and three-degree-of-freedom trajectory results are compared to assess the entry characteristics of the capsule. Comparison of the preentry results to preliminary post-landing reconstruction data shows that all EDL parameters were within the requirements. In addition, the final landing position for both ‘Spirit’ and ‘Opportunity’ were within 15 km of the predicted landing location.
Author
Trajectory Analysis; Mars Landing; Roving Vehicles; Position (Location)

20040086474 NASA Langley Research Center, Hampton, VA, USA
Aeroassist Technology Planning for Exploration
Munk, Michelle M.; Powell, Richard W.; [2000]; In English
Report No.(s): AAS-00-169; No Copyright; Avail: CASI; A03, Hardcopy

Now that the International Space Station is undergoing assembly, NASA is strategizing about the next logical exploration strategy for robotic missions and the next destination for humans. NASA’s current efforts are in developing technologies that will both aid the robotic exploration strategy and make human flight to other celestial bodies both safe and affordable. One of these enabling technologies for future robotic and human exploration missions is aeroassist. This paper will (1) define aeroassist, (2) explain the benefits and uses of aeroassist, and (3) describe a method, currently used by the NASA Aeroassist Working Group, by which widely geographically distributed teams can assemble, present, use, and archive technology information.
Author
Aeroassist; International Space Station; NASA Space Programs; Space Exploration; Technological Forecasting

20040085958 Morgan Research Corp., Huntsville, AL, USA, NASA Marshall Space Flight Center, Huntsville, AL, USA
Atmospheric Models for Aerocapture
Justus, C. G.; Duvall, Aleta L.; Keller, Vernon W.; April 09, 2004; In English, 11-14 Jul. 2004, Fort Lauderdale, FL, USA
Contract(s)/Grant(s): NNM04AA02C; No Copyright; Avail: CASI; A02, Hardcopy

There are eight destinations in the solar System with sufficient atmosphere for aerocapture to be a viable aeroassist option - Venus, Earth, Mars, Jupiter, Saturn and its moon Titan, Uranus, and Neptune. Engineering-level atmospheric models for four of these targets (Earth, Mars, Titan, and Neptune) have been developed for NASA to support systems analysis studies of potential future aerocapture missions. Development of a similar atmospheric model for Venus has recently commenced. An important capability of all of these models is their ability to simulate quasi-random density perturbations for Monte Carlo analyses in developing guidance, navigation and control algorithm, and for thermal systems design. Similarities and differences among these atmospheric models are presented, with emphasis on the recently developed Neptune model and on planned characteristics of the Venus model. Example applications for aerocapture are also presented and illustrated. Recent updates to the Titan atmospheric model are discussed, in anticipation of applications for trajectory and atmospheric reconstruct of Huygens Probe entry at Titan.
Author
Atmospheric Models; Aerocapture; Huygens Probe; Environmental Monitoring

20040085708 NASA Langley Research Center, Hampton, VA, USA
Aeroheating Thermal Analysis Methods for Aerobraking Mars Missions
Amundsen, Ruth M.; Dec, John A.; George, Benjamin E.; [2002]; In English; No Copyright; Avail: CASI; A03, Hardcopy

Mars missions often employ aerobraking upon arrival at Mars as a low-mass method to gradually reduce the orbit period from a high-altitude, highly elliptical insertion orbit to the final science orbit. Two recent missions that made use of aerobraking were Mars Global Surveyor (MGS) and Mars Odyssey. Both spacecraft had solar arrays as the main aerobraking surface area. Aerobraking produces a high heat load on the solar arrays, which have a large surface area exposed to the airflow and relatively low mass. To accurately model the complex behavior during aerobraking, the thermal analysis must be tightly coupled to the flight mechanics, aerodynamics, and atmospheric modeling efforts being performed during operations. To properly represent the temperatures prior to and during the drag pass, the model must include the orbital solar and planetary heat fluxes. The correlation of the thermal model to flight data allows a validation of the modeling process, as well as

information on what processes dominate the thermal behavior. This paper describes the thermal modeling method that was developed for this purpose, as well as correlation for two flight missions, and a discussion of improvements to the methodology.
Author
Aerobraking; Mars Missions; Elliptical Orbits; Thermal Analysis; Aerodynamic Heating

20040068067 Computer Sciences Corp., Huntsville, AL, USA
Connecting Atmospheric Science and Atmospheric Models for Aerocaptured Missions to Titan and the Outer Planets
Justus, C. G.; Duvall, Aleta; Keller, Vernon W.; December 19, 2003; In English, 25-30 Apr. 2004, Nice, France
Contract(s)/Grant(s): NAS8-60000; No Copyright; Avail: Other Sources; Abstract Only

Many atmospheric measurement systems, such as the sounding instruments on Voyager, gather atmospheric information in the form of temperature versus pressure level. In these terms, there is considerable consistency among the mean atmospheric profiles of the outer planets Jupiter through Neptune, including Titan. On a given planet or on Titan, the range of variability of temperature versus pressure level due to seasonal, latitudinal, and diurnal variations is also not large. However, many engineering needs for atmospheric models relate not to temperature versus pressure level but atmospheric density versus geometric altitude. This need is especially true for design and analysis of aerocapture systems. Aerocapture drag force available for aerocapture is directly proportional to atmospheric density. Available aerocapture 'corridor width' (allowable range of atmospheric entry angle) also depends on height rate of change of atmospheric density, as characterized by density scale height. Characteristics of hydrostatics and the gas law equation mean that relatively small systematic differences in temperature-versus-pressure profiles can integrate at high altitudes to very large differences in density-versus-altitude profiles. Thus a given periapsis density required to accomplish successful aerocapture can occur at substantially different altitudes (approx. 150 - 300 km) on the various outer planets, and significantly different density scale heights (approx. 20 - 50 km) can occur at these periapsis altitudes. This paper will illustrate these effects and discuss implications for improvements in atmospheric measurements to yield significant impact on design of aerocapture systems for future missions to Titan and the outer planets. Relatively small- scale atmospheric perturbations, such as gravity waves, tides, and other atmospheric variations can also have significant effect on design details for aerocapture guidance and control systems. This paper will also discuss benefits that would result from improved understanding of Titan and outer planetary atmospheric perturbation characteristics. Details of recent engineering-level atmospheric models for Titan and Neptune will be presented, and effects of present and future levels of atmospheric uncertainty and variability characteristics will be examined.
Author
Atmospheric Physics; Atmospheric Models; Aerocapture; Planetary Atmospheres; Atmospheric Density; Annual Variations

20040062499 Lunar and Planetary Inst., Houston, TX, USA
Lunar and Planetary Science XXXV: Missions and Instruments: Hopes and Hope Fulfilled
2004; In English; Lunar and Planetary Science XXXV, 15-19 Mar. 2004, Houston, TX, USA
Contract(s)/Grant(s): NCC5-679
Report No.(s): LPI-Contrib-1197; Copyright; Avail: CASI; C01, CD-ROM

The titles in this section include: 1) Mars Global Surveyor Mars Orbiter Camera in the Extended Mission: The MOC Toolkit; 2) Mars Odyssey THEMIS-VIS Calibration; 3) Early Science Operations and Results from the ESA Mars Express Mission: Focus on Imaging and Spectral Mapping; 4) The Mars Express/NASA Project at JPL; 5) Beagle 2: Mission to Mars - Current Status; 6) The Beagle 2 Microscope; 7) Mars Environmental Chamber for Dynamic Dust Deposition and Statics Analysis; 8) Locating Targets for CRISM Based on Surface Morphology and Interpretation of THEMIS Data; 9) The Phoenix Mission to Mars; 10) First Studies of Possible Landing Sites for the Phoenix Mars Scout Mission Using the BMST; 11) The 2009 Mars Telecommunications Orbiter; 12) The Aurora Exploration Program - The ExoMars Mission; 13) Electron-induced Luminescence and X-Ray Spectrometer (ELXS) System Development; 14) Remote-Raman and Micro-Raman Studies of Solid CO2, CH4, Gas Hydrates and Ice; 15) The Compact Microimaging Spectrometer (CMIS): A New Tool for In-Situ Planetary Science; 16) Preliminary Results of a New Type of Surface Property Measurement Ideal for a Future Mars Rover Mission; 17) Electrodynamic Dust Shield for Solar Panels on Mars; 18) Sensor Web for Spatio-Temporal Monitoring of a Hydrological Environment; 19) Field Testing of an In-Situ Neutron Spectrometer for Planetary Exploration: First Results; 20) A Miniature Solid-State Spectrometer for Space Applications - Field Tests; 21) Application of Laser Induced Breakdown Spectroscopy (LIBS) to Mars Polar Exploration: LIBS Analysis of Water Ice and Water Ice/Soil Mixtures; 22) LIBS Analysis of Geological Samples at Low Pressures: Application to Mars, the Moon, and Asteroids; 23) In-Situ 1-D and 2-D Mapping of Soil Core and Rock Samples Using the LIBS Long Spark; 24) Rocks Analysis at Stand Off Distance by LIBS in Martian Conditions; 25) Evaluation of a Compact Spectrograph/Detection System for a LIBS Instrument for In-Situ and Stand-Off Detection; 26)

Analysis of Organic Compounds in Mars Analog Samples; 27) Report of the Organic Contamination Science Steering Group; 28) The Water-Wheel IR (WIR) - A Contact Survey Experiment for Water and Carbonates on Mars; 29) Mid-IR Fiber Optic Probe for In Situ Water Detection and Characterization; 30) Effects of Subsurface Sampling & Processing on Martian Simulant Containing Varying Quantities of Water; 31) The Subsurface Ice Probe (SIPR): A Low-Power Thermal Probe for the Martian Polar Layered Deposits; 32) Deploying Ground Penetrating Radar in Planetary Analog Sites to Evaluate Potential Instrument Capabilities on Future Mars Missions; 33) Evaluation of Rock Powdering Methods to Obtain Fine-grained Samples for CHEMIN, a Combined XRD/XRF Instrument; 34) Novel Sample-handling Approach for XRD Analysis with Minimal Sample Preparation; 35) A New Celestial Navigation Method for Mars Landers; 36) Mars Mineral Spectroscopy Web Site: A Resource for Remote Planetary Spectroscopy.
CASI
Spacecraft Instruments; Planetology; Mars Missions

20040039671

Multibody Parachute Flight Simulations for Planetary Entry Trajectories Using 'Equilibrium Points'

Raiszadeh, Ben; Advances in the Astronautical Sciences; 2003; ISSN 0065-3438; Volume 114, Issue SUPPL., p. 903-914; In English; Copyright; Avail: Other Sources

A method has been developed to reduce numerical stiffness and computer CPU requirements of high fidelity multibody flight simulations involving parachutes for planetary entry trajectories. Typical parachute entry configurations consist of entry bodies suspended from a parachute, connected by flexible lines. To accurately calculate line forces and moments, the simulations need to keep track of the point where the flexible lines meet (confluence point). In previous multibody parachute flight simulations, the confluence point has been modeled as a point mass. Using a point mass for the confluence point tends to make the simulation numerically stiff, because its mass is typically much less that than the main rigid body masses. One solution for stiff differential equations is to use a very small integration time step. However, this results in large computer CPU requirements. In the method described in the paper, the need for using a mass as the confluence point has been eliminated. Instead, the confluence point is modeled using an 'equilibrium point'. This point is calculated at every integration step as the point at which sum of all line forces is zero (static equilibrium). The use of this 'equilibrium point' has the advantage of both reducing the numerical stiffness of the simulations, and eliminating the dynamical equations associated with vibration of a lumped mass on a high-tension string.
EI
Computers; Parachutes; Spacecraft; Stiffness; Trajectories

20040039371

Approach navigation for the 2009 Mars large lander

Burkhart, P. Daniel; Advances in the Astronautical Sciences; 2003; ISSN 0065-3438; Volume 114, Issue SUPPL., p. 2181-2196; In English; Copyright; Avail: Other Sources

The current Mars exploration plan envisions the launch of a large lander in the 2009 launch opportunity with a soft landing on Mars in the fall of 2010. The goal is to achieve a landed surface position within 10km of the target landing site. Current entry descent and landing (EDL) analysis shows that the largest contributor to the landed position error is uncertainty of the initial conditions, which are supplied by the ground-based navigation process. The focus of this paper is the performance of the approach navigation process using combinations of Deep Space Network (DSN) Doppler, ranging and delta differential one-way range (delta DOR) measurements along with optical navigation data collected by the spacecraft. Results for several combinations of data types will be included.
EI
Data Acquisition; Navigation; Planetary Landing; Roving Vehicles; Trajectories

20040039331

Optical landmark detection for spacecraft navigation

Cheng, Yang; Johnson, Andrew E.; Matthies, Larry H.; Olson, Clark F.; Advances in the Astronautical Sciences; 2003; ISSN 0065-3438; Volume 114, Issue SUPPL., p. 1767-1785; In English; Copyright; Avail: Other Sources

Optical landmark navigation using craters on the surface of a central body was first used operationally by the Near Earth Asteroid Rendezvous (NEAR) mission. It has proven to be a powerful data type for determining spacecraft orbits above the target for close flybys and low altitude orbiting. Tracking individual landmarks, which are small craters, enables orbit determination accuracies on the order of the camera resolution or several meters. This exceeds the accuracy that can be

obtained from radiometric data alone. Currently, most of optical landmark navigation operations, such as crater detection, tracking, and matching etc, are done manually, which is extremely time consuming, tedious and sometime unmanageable. Because of the lengthily operation time and the deep-space communication delay, manual operation cannot meet the requirements of rapid and precise spacecraft maneuvers such as close orbiting, fast flybys and landing. Automating this operation can greatly improve navigation accuracy and efficiency and ultimately lead to an on-board autonomous navigation capability. In this paper, a new crater detection algorithm is suggested. Experimental studies show that this new algorithm can achieve sub-pixel accuracy in position, its detection rate is better than 90% and its false alarm rate is less than 5%. These good characteristics indicate that it is an ideal crater detection algorithm for spacecraft optical navigation.
EI

Cameras; Navigation; Resolution; Spacecraft Propulsion; Tracking (Position)

20040039275

Daily repeat-groundtrack Mars orbits

Noreen, Gary; Kerridge, Stuart; Diehl, Roger; Neelon, Joseph; Ely, Todd; Turner, Andrew E.; Advances in the Astronautical Sciences; 2003; ISSN 0065-3438; Volume 114, Issue SUPPL., p. 1143-1155; In English; Copyright; Avail: Other Sources

This paper derives orbits at Mars with groundtracks that repeat at the same times every solar day (sol). A relay orbiter in such an orbit would pass over in-situ probes at the same times every sol, ensuring consistent coverage and simplifying mission design and operations. 42 orbits in five classes are characterized: 14 circular equatorial prograde orbits 14 circular equatorial retrograde orbits 11 circular sun synchronous orbits 2 eccentric equatorial orbits 1 eccentric critically inclined orbit The paper reports on the performance of a relay orbiter in some of the orbits.
EI

Aerospace Sciences; Communication Satellites; Ground Tracks; Orbits; Planetary Landing; Planets

20040038205

Entry trajectory and atmosphere reconstruction methodologies for the mars exploration rover mission

Desai, Prasun N.; Blanchard, Robert C.; Powell, Richard W.; European Space Agency, (Special Publication) ESA SP; February 2004; ISSN 0379-6566, Issue no. 544, p. 213-220; In English; International Workshop: Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science, Oct. 6-9, 2003, Lisbon, Portugal; Copyright; Avail: Other Sources

The Mars Exploration Rover (MER) mission will land two landers on the surface of Mars, arriving in January 2004. Both landers will deliver the rovers to the surface by decelerating with the aid of an aeroshell, a supersonic parachute, retro-rockets, and air bags for safely landing on the surface. The reconstruction of the MER descent trajectory and atmosphere profile will be performed for all the phases from hypersonic flight through landing. A description of multiple methodologies for the flight reconstruction is presented from simple parameter identification methods through a statistical Kalman filter approach.
EI

Air Bag Restraint Devices; Kalman Filters; Parachutes; Planetary Landing; Trajectories

20040038193

Entry descent, and landing scenario for the Mars exploration Rover mission

Desai, Prasun N.; Lee, Wayne J.; European Space Agency, (Special Publication) ESA SP; February 2004; ISSN 0379-6566, Issue no. 544, p. 31-36; In English; International Workshop: Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science, Oct. 6-9, 2003, Lisbon, Portugal; Copyright; Avail: Other Sources

In January 2004, the Mars Exploration Rover (MER) mission will land two landers on the surface of Mars. Both landers will deliver a rover to the surface using an entry, descent, and landing (EDL) scenario based on Mars Pathfinder heritage. However, the entry conditions and environments are different from that of Mars Pathfinder. Unique challenges are present due to the entry differences of a heavier entry mass, less dense atmosphere, and higher surface landing site altitude. These differences result in a higher terminal velocity and less time for performing all the EDL events as compared to Mars Pathfinder. As a result of these differences, modifications are made to the MER EDL systems to safely deliver the rovers to the surface of Mars.
EI

Aerospace Sciences; Planetary Landing; Planets; Roving Vehicles; Topography

20040038111

Thermal protection system technology and facility needs for demanding future planetary missions

Laub, B.; Venkatapathy, E.; European Space Agency, (Special Publication) ESA SP; February 2004; ISSN 0379-6566, Issue no. 544, p. 239-247; In English; International Workshop: Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science, Oct. 6-9, 2003, Lisbon, Portugal; Copyright; Avail: Other Sources

NASA has successfully launched numerous science missions to inner and outer planets in our solar system of which the most challenging were to Venus and Jupiter and the knowledge gained from those missions have been invaluable yet incomplete. Future missions will be built on what we have learned from the past missions but they will be more demanding from both the science as well as the mission design and engineering perspectives. The Solar System Exploration Decadal Survey (SSEDS) produced for NASA by the National Research Council identified a broad range of science objectives many of which can only be satisfied with atmospheric entry probes. The SSEDS recommended new probe/lander missions to both Venus and Jupiter. The Pioneer-Venus probe mission was launched in August 1978 and four probes successfully entered the Venusian atmosphere in December 1978. The Galileo mission was launched in October 1989 and one probe successfully entered the Jovian atmosphere in December 1995. The thermal protection system requirements for these two missions were unlike any other planetary probes and required fully dense carbon phenolic for the forebody heat shield. Developing thermal protection systems to accomplish future missions outlined in the Decadal Survey presents a technology challenge since they will be more demanding than these past missions. Unlike Galileo, carbon phenolic may not be an adequate TPS for a future Jupiter multiprobe mission since non-equatorial probes will enter at significantly higher velocity than the Galileo equatorial probe and the entry heating scales approximately with the cube of the entry velocity. At such heating rates the TPS mass fraction for a carbon phenolic heat shield would be prohibitive. A new, robust and efficient TPS is required for such probes. The Giant Planet Facility (GPF), developed and employed during the development of the TPS for the Galileo probe was dismantled after completion of the program. Furthermore, flight data from the Galileo probe suggested that the complex physics associated with the interaction between massive ablation and a severe shock layer radiation environment is not well understood or modeled. The lack of adequate ground test facilities to support the development and qualification of new TPS materials adds additional complexities. The requirements for materials development, ground testing and sophisticated modeling to enable these challenging missions are the focus of this paper.

EI

Aerospace Sciences; Heat Shielding; Planetary Landing; Space Probes; Vaporizing

20040038093

Ultra-stable oscillators for planetary entry probes

Asmar, S. W.; Atkinson, D. H.; Bird, M. K.; Wood, G. E.; European Space Agency, (Special Publication) ESA SP; February 2004; ISSN 0379-6566, Issue no. 544, p. 131-134; In English; International Workshop: Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science, Oct. 6-9, 2003, Lisbon, Portugal; Copyright; Avail: Other Sources

Ultra-stable oscillators on-board planetary missions were developed for Radio Science instrumentation, functioning as frequency references for the one-way downlink during atmospheric occultations. They have also been flown on planetary entry probes including the Jupiter entry probe, carried by Galileo, and the Huygens Titan entry probe, carried by Cassini, for performing Doppler Wind Experiments. The Jupiter and Titan probes utilized different oscillators, quartz and rubidium, respectively. This paper presents the development of ultra-stable oscillators on deep space missions and discusses the tradeoffs encountered when selecting oscillators for planetary entry probes, including factors such as duration of the experiment, the available warm-up time and the Allan deviation and phase noise requirements.

EI

Mechanical Oscillators; Quartz; Rubidium; Transponders

20040038075

Pioneer Venus and Galileo entry probe heritage

Bienstock, Bernard J.; European Space Agency, (Special Publication) ESA SP; February 2004; ISSN 0379-6566, Issue no. 544, p. 37-45; In English; International Workshop: Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science, Oct. 6-9, 2003, Lisbon, Portugal; Copyright; Avail: Other Sources

Beginning in the late 1960s, NASA began planning for its first program to explore Venus. Although planetary entry probes had been flown to Venus by the Soviets beginning in 1967, NASA had not previously flown this type of mission, The Space and Communications Group of Hughes Aircraft Company, now owned by Boeing and called Boeing Satellite Systems, worked with NASA to perform initial studies that culminated with a contract for the Pioneer Venus program in early 1974, Pioneer Venus was an ambitious program that included four planetary entry probes, transported to Venus by a Multiprobe Bus, and

a Venus Orbiter. This paper focuses on the engineering aspects of the probes and the challenges overcome in accommodating the various scientific instruments. The second NASA planetary entry program was the Galileo Mission that began with initial studies in the early 1970s. This mission to Jupiter included both an Orbiter and a Probe. Although the Galileo Probe planetary entry program was begun as the Pioneer Venus probes were heading towards Venus, there were significant engineering differences between the Pioneer Venus probe designs and the Galileo Probe. These differences, dictated by a number of factors, are discussed. The paper concludes with a summary of lessons learned by Boeing and NASA in designing, manufacturing and ultimately flying the Venus and Jupiter planetary entry probes.
EI
Aerospace Sciences; Galileo Spacecraft; Planets; Pressure Vessels; Space Probes; Venus (Planet)

20040038071
Summary of the Boulder Entry Probe Workshop April 21-22, 2003, Boulder, Colorado, USA
Young, Richard E.; Atkinson, David; Atreya, Sushil; Banfield, Donald; Beebe, Reta; Bolton, Scott; Briggs, Geoffrey; Crisp, David; Cutts, James; Drake, Michael; Esposito, Larry; Galal, Kenneth; Hubbard, William; Hunten, Donald; Ingersoll, Andrew; et al., T; European Space Agency, (Special Publication) ESA SP; February 2004; ISSN 0379-6566, Issue no. 544, p. 13-20; In English; International Workshop: Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science, Oct. 6-9, 2003, Lisbon, Portugal; Copyright; Avail: Other Sources

The Solar System Exploration Decadal Survey (SSEDS) identified several high priority Solar System Key Science Questions that should be addressed by entry probes/landers, or that should be addressed simultaneously by both probes/landers and remote sensing types of observations. These Key Science Questions are directly relevant to Goals and Objectives of the NASA Strategic Plan and Office of Space Science Strategic Plan. In this report we define entry probes/landers as spacecraft that sample in-situ a planetary atmosphere, and planetary surface if there is one. The Entry Probe Workshop grew out of a community concern that if entry probes/landers were to be a viable mission option for addressing the overarching questions identified in the SSEDS in the coming 10-15 years, significant resources must be applied to key technology areas immediately. The major science objectives requiring entry probes and the key technology development areas for probes are described.
EI
Aerospace Sciences; Meteorites; Periodic Variations; Planetary Landing; Planets; Space Probes

20040037789 NASA Langley Research Center, Hampton, VA, USA
Angle-of-Attack-Modulated Terminal Point Control for Neptune Aerocapture
Queen, Eric M.; [2004]; In English, 8-12 Feb. 2004, Maui, HI, USA
Contract(s)/Grant(s): 800-90-50
Report No.(s): AAS-04-129; Copyright; Avail: CASI; A02, Hardcopy

An aerocapture guidance algorithm based on a calculus of variations approach is developed, using angle of attack as the primary control variable. Bank angle is used as a secondary control to alleviate angle of attack extremes and to control inclination. The guidance equations are derived in detail. The controller has very small onboard computational requirements and is robust to atmospheric and aerodynamic dispersions. The algorithm is applied to aerocapture at Neptune. Three versions of the controller are considered with varying angle of attack authority. The three versions of the controller are evaluated using Monte Carlo simulations with expected dispersions.
Author
Algorithms; Aerocapture; Angle of Attack; Neptune (Planet); Control Theory; Terminal Guidance

20040037788 NASA Langley Research Center, Hampton, VA, USA
Mars Exploration Rover Terminal Descent Mission Modeling and Simulation
Raiszadeh, Behzad; Queen, Eric M.; February 2004; In English, 8-12 Feb. 2004, Maui, HI, USA
Contract(s)/Grant(s): 759-30-00
Report No.(s): AAS-04-271; No Copyright; Avail: CASI; A03, Hardcopy

Because of NASA's added reliance on simulation for successful interplanetary missions, the MER mission has developed a detailed EDL trajectory modeling and simulation. This paper summarizes how the MER EDL sequence of events are modeled, verification of the methods used, and the inputs. This simulation is built upon a multibody parachute trajectory simulation tool that has been developed in POST I1 that accurately simulates the trajectory of multiple vehicles in flight with interacting forces. In this model the parachute and the suspended bodies are treated as 6 Degree-of-Freedom (6 DOF) bodies. The terminal descent phase of the mission consists of several Entry, Descent, Landing (EDL) events, such as parachute

deployment, heatshield separation, deployment of the lander from the backshell, deployment of the airbags, RAD firings, TIRS firings, etc. For an accurate, reliable simulation these events need to be modeled seamlessly and robustly so that the simulations will remain numerically stable during Monte-Carlo simulations. This paper also summarizes how the events have been modeled, the numerical issues, and modeling challenges.

Author

Mars Exploration; Mars Roving Vehicles; Descent; Space Missions; Mathematical Models; Trajectory Analysis; Computerized Simulation

20040024535

Planning for a Mars in situ sample preparation and distribution (SPAD) system

Beaty, D. W.; Miller, S.; Zimmerman, W.; Bada, J.; Conrad, P.; Dupuis, E.; Huntsberger, T.; Ivlev, R.; Kim, S. S.; Lee, B. G.; Lindstrom, D.; Lorenzoni, L.; Mahaffy, P.; McNamara, K.; Papanastassiou, D.; et al., T; Planetary and Space Science; January/March 2004; ISSN 0032-0633; Volume 52, Issue no. 1-3, p. 55-66; In English; Copyright; Avail: Other Sources

For Mars in situ landed missions, it has become increasingly apparent that significant value may be provided by a shared system that we call a Sample Preparation and Distribution (SPAD) System. A study was conducted to identify the issues and feasibility of such a system for these missions that would provide common functions for: receiving a variety of sample types from multiple sample acquisition systems; conducting preliminary characterization of these samples with non-destructive science instruments and making decisions about what should happen to the samples; performing a variety of sample preparation functions; and, finally, directing the prepared samples to additional science instruments for further analysis. Scientific constraints on the functionality of the system were identified, such as triage, contamination management, and various sample preparation steps, e.g., comminution, splitting, rock surfacing, and sieving. Some simplifying strategies were recommended and an overall science flow was developed. Engineering functional requirements were also investigated and example architectures developed. Preliminary conclusions are that shared SPAD facility systems could indeed add value to future Mars in situ landed missions if they are designed to respond to the particular requirements and constraints of those missions, that such a system appears feasible for consideration, and that certain standards should be developed for key SPAD interfaces. (copyright) 2003 Elsevier Ltd. All rights reserved.

EI

Aerospace Sciences; In Situ Measurement; Planetary Landing; Spacecraft

20040024261

Blended control, predictor-corrector guidance algorithm: An enabling technology for Mars aerocapture

Jits, Roman Y.; Walberg, Gerald D.; Acta Astronautica; March 2004; ISSN 0094-5765; Volume 54, Issue no. 6, p. 385-398; In English; Copyright; Avail: Other Sources

A guidance scheme designed for coping with significant dispersion in the vehicle's state and atmospheric conditions is presented. In order to expand the flyable aerocapture envelope, control of the vehicle is realized through bank angle and angle-of-attack modulation. Thus, blended control of the vehicle is achieved, where the lateral and vertical motions of the vehicle are decoupled. The overall implementation approach is described, together with the guidance algorithm macrologic and structure. Results of guidance algorithm tests in the presence of various single and multiple off-nominal conditions are presented and discussed. (copyright) 2003 Published by Elsevier Ltd.

EI

Aerospace Sciences; Astrophysics; Atmospheric Chemistry; Interplanetary Spacecraft; Planets; Predictor-Corrector Methods

20040012726 NASA Marshall Space Flight Center, Huntsville, AL, USA

SEP Mission to Titan NEXT Aerocapture In-Space Propulsion (Quicktime Movie)

Baggett, Randy; TECH ISP: Next Generation Ion; January 2004; In English; No Copyright; Avail: CASI; A01, Hardcopy

The ion thruster is one of the most promising solar electric propulsion (SEP) technologies to support future Outer Planet missions (place provided link below here) for NASA's Office of Space Science. Typically, ion thrusters are used in high Isp-low thrust applications that require long lifetimes, as well as, higher efficiency over state-of-the-art chemical propulsion systems.Today, the standard for ion thrusters is the SEP Technology Application Readiness (NSTAR) thruster. Jet Propulsion Laboratory's (JPL's) extended life test (ELT) of the DS 1 flight spare NSTAR thruster began in October 1998. This test successfully demonstrated lifetime of the NSTAR flight spare thruster, which will provide a solid basis for selection of ion thrusters for future Code S missions. The NSTAR ELT was concluded on June 30,2003 after 30,352 hours. The purpose of the Next Generation Ion (NGI) activities is to advance Ion propulsion system technologies through the development of

NASA's Evolutionary Xenon Thruster (NEXT). The goal of NEXT is to more than double the power capability and lifetime throughput (the total amount of propellant which can be processed) while increasing the Isp by 30% and the thrust by 120%.
Derived from text
Ion Propulsion; Solar Electric Propulsion

20030111896 Naval Postgraduate School, Monterey, CA
Optimization of Low Thrust Trajectories With Terminal Aerocapture
Josselyn, Scott B.; Jun. 2003; In English; Original contains color illustrations
Report No.(s): AD-A417512; No Copyright; Avail: CASI; A08, Hardcopy

This thesis explores using a direct pseudospectral method for the solution of optical control problems with mixed dynamics. An easy to use MATLAB optimization package known as DIDO is used to obtain the solutions. The modeling of both low thrust interplanetary trajectories as well as aerocapture trajectories is detailed and the solutions for low thrust minimum time and minimum fuel trajectories are explored with particular emphasis on verification of the optimality of the obtained solution. Optimal aerocapture trajectories are solved for rotating atmospheres over a range of arrival V- infinities. Solutions are obtained using various performance indexes including minimum fuel, minimum heat load, and minimum total aerocapture mass. Finally, the problem formulation and solutions for the mixed dynamic problem of low thrust trajectories with a terminal aerocapture maneuver is addressed yielding new trajectories maximizing the total scientific mass at arrival. This thesis explores using a direct pseudospectral method for the solution of optimal control problems with mixed dynamics. An easy to use MATLAB optimization package known as DIDO is used to obtain the solutions. The modeling of both low thrust interplanetary trajectories as well as aerocapture trajectories is detailed and the solutions for low thrust minimum time and minimum fuel trajectories are explored with particular emphasis on verification of the optimality of the obtained solution. Optimal aerocapture trajectories are solved for rotating atmospheres over a range of arrival V-infinities. Solutions are obtained using various performance indexes including minimum fuel, minimum heat load, and minimum total aerocapture mass. Finally, the problem formulation and solutions for the mixed dynamic problem of low thrust trajectories with a terminal aerocapture maneuver is addressed yielding new trajectories maximizing the total scientific mass at arrival.
DTIC
Interplanetary Trajectories; Interorbital Trajectories; Trajectory Optimization; Optimal Control

20030107097 Air Force Inst. of Tech., Wright-Patterson AFB, OH
Aerocapture Guidance Methods for High Energy Trajectories
Dicarlo, Jennifer L.; May 23, 2003; In English
Report No.(s): AD-A416545; AFIT-CI02-1191; No Copyright; Avail: CASI; A07, Hardcopy

This thesis investigates enhancements of an existing numerical predictor-corrector aerocapture guidance algorithm (PredGuid). The study includes implementation of an energy management phase prior to targeting with a generic method of transition and replacement of heuristic features with more generic features. The vehicle response during energy management was modeled as a second-order spring/mass/damper system. Phase change occurred when two conditions were met: First, the vehicle could fly a constant bank angle of 1100 for the remainder of the trajectory and have the resulting apogee below or within a given tolerance above the target apogee. Second, the predicted final energy indicated that the vehicle would be on an elliptical, not hyperbolic, trajectory. So as to incorporate generic features, modeling of a separate lift down phase was replaced by using a lift-down condition to determine phase change and biasing to the same lift- down condition during targeting. Also, use of a heuristic sensitivity to calculate the first corrected bank angle was replaced by a simple smart guessing' algorithm. Finally, heuristic lateral corridor boundaries were replaced by boundaries based on percentage of forward velocity.
DTIC
Trajectories; Hyperbolic Trajectories; Predictor-Corrector Methods; Algorithms

20030106653 NASA Marshall Space Flight Center, Huntsville, AL, USA
Aerocapture Technology Project Overview
James, Bonnie; Munk, Michelle; Moon, Steve; July 20, 2003; In English
Report No.(s): AIAA Paper 2003-4654; No Copyright; Avail: CASI; A01, Hardcopy

Aerocapture technology development is one of the highest priority investments for the NASA In-Space Propulsion Program (ISP). The ISP is managed by the NASA Headquarters Office of Space Science, and implemented by the Marshall Space Flight Center in Huntsville, Alabama. The objective of the ISP Aerocapture Technology Project (ATP) is to develop

technologies that can enable and/or benefit NASA science missions by significantly reducing cost, mass, and trip times. To accomplish this objective, the ATP identifies and prioritizes the most promising technologies using systems analysis, technology advancement and peer review, coupled with NASA Headquarters Office of Space Science target requirements. Efforts are focused on developing mid-Technology Readiness Level (TRL) technologies to systems-level spaceflight validation.

Author

Aerocapture; Systems Analysis; Spacecraft Propulsion

20030106138 Ball Aerospace and Technologies Corp., Boulder, CO, USA

Trailing Ballute Aerocapture: Concept and Feasibility Assessment

Miller, Kevin L.; Gulick, Doug; Lewis, Jake; Trochman, Bill; Stein, Jim; Lyons, Daniel T.; Wilmoth, Richard G.; July 21, 2003; In English; AIAA Joint Propulsion Conference and Exhibit 2003, 20-23 Jul. 2003, Huntsville, AL, USA

Contract(s)/Grant(s): NAS8-02130; JPL-1205966

Report No.(s): AIAA Paper 2003-4655; Copyright; Avail: CASI; A03, Hardcopy

Trailing Ballute Aerocapture offers the potential to obtain orbit insertion around a planetary body at a fraction of the mass of traditional methods. This allows for lower costs for launch, faster flight times and additional mass available for science payloads. The technique involves an inflated ballute (balloon-parachute) that provides aerodynamic drag area for use in the atmosphere of a planetary body to provide for orbit insertion in a relatively benign heating environment. To account for atmospheric, navigation and other uncertainties, the ballute is oversized and detached once the desired velocity change (Delta V) has been achieved. Analysis and trades have been performed for the purpose of assessing the feasibility of the technique including aerophysics, material assessments, inflation system and deployment sequence and dynamics, configuration trades, ballute separation and trajectory analysis. Outlined is the technology development required for advancing the technique to a level that would allow it to be viable for use in space exploration missions.

Author

Ballutes; Aerocapture; Aerodynamic Drag; Feasibility Analysis

20030105420

Mars reconnaissance orbiter design approach for high-resolution surface imaging

Lee, S. W.; Skulsky, E. D.; Chapel, J.; Cwynar, D.; Gehling, R.; Delamere, A.; Advances in the Astronautical Sciences; 2003; ISSN 0065-3438; Volume 113, p. 509-528; In English; Guidance and Control 2003: Advances in the Astronautical Sciences, Feb. 5-9, 2003, Breckenridge, CO, USA; Copyright; Avail: Other Sources

The Mars Reconnaissance Orbiter (MRO) will explore Mars equipped with a suite of six scientific instruments and two engineering experiments, and supporting two additional facility investigations. One of the objectives of the MRO mission is to use the High-Resolution Imaging Science Experiment (HiRISE) to provide 30 cm/pixel images of future Mars landing sites. To achieve such detail, MRO must meet some very challenging target-relative pointing and pointing stability requirements. A combination of analysis, operational constraints, and spacecraft design modifications were utilized to ensure that the necessary pointing requirements will be met.

EI

High Resolution; Imaging Techniques; Orbits; Reconnaissance Aircraft

20030091868

Pitch control during autonomous aerobraking for near-term Mars exploration

Johnson, Wyatt R.; Longuski, James M.; Lyons, Daniel T.; Journal of Spacecraft and Rockets; May/June 2003; ISSN 0022-4650; Volume 40, Issue no. 3, p. 371-379; In English; Copyright; Avail: Other Sources

Conventional aerobraking requires propellant to dump the spacecraft's angular momentum and to maintain attitude control during the atmospheric flythrough. We consider how reaction wheels can be used to control the spacecraft's pitch during each atmospheric flythrough and to reduce angular momentum simultaneously. Control laws are developed for minimum onboard instrumentation (where the only state information are the angular rates of the spacecraft and the reaction wheels) to compensate for large variations in entry time and atmospheric density. Simulations indicate that pitch attitude and angular momentum can be controlled with reaction wheels alone, thus saving precious propellant while significantly increasing the timing margin for sequencing.

EI

Aerodynamics; Computerized Simulation; Drag; Spacecraft

20030080878

AIMS: Acousto-optic imaging spectrometer for spectral mapping of solid surfaces

Glenar, David A.; Blaney, Diana L.; Hillman, John J.; Acta Astronautica; January/March 2003; ISSN 0094-5765; Volume 52, Issue no. 2-6, p. 389-396; In English; Copyright; Avail: Other Sources

A compact, two-channel acousto-optic tunable filter (AOTF) camera is being built at GSFC as a candidate payload instrument for future Mars landers or small-body rendezvous missions. This effort is supported by the NASA Mars Instrument Development Program (MIDP), Office of Space Science Advanced Technologies and Mission Studies. Acousto-optic Imaging Spectrometer (AIMS) is electronically programmable and provides arbitrary spatial and spectral selection from 0.48 to 2.4 mu m. The geometric throughput of AOTF's are well matched to the requirements for lander mounted cameras since (I) they can be made very compact, (II) 'slow' (f/14-f/18) optics required for large depth-of-field fall well within the angular aperture limit of AOTF's, and (III) they operate at low ambient temperatures. A breadboard of the AIMS short-wavelength channel is now being used for spectral imaging of high-interest Mars analog materials (iron oxides, carbonates, sulfates and sedimentary basalts) as part of the initial instrument validation exercises. (copyright) 2002 Published by Elsevier Science Ltd.

EI

Acousto-Optics; Aerospace Sciences; Cameras; Imaging Techniques; Planetary Landing

20030080863

Europa Lander

Gershman, Robert; Nilsen, Erik; Oberto, Robert; Acta Astronautica; January/March 2003; ISSN 0094-5765; Volume 52, Issue no. 2-6, p. 253-258; In English; Copyright; Avail: Other Sources

A Europa Lander mission has been assigned high priority for the post-2005 time frame in NASA's Space Science Enterprise Strategic Plan. Europa is one of the most scientifically interesting objects in the solar system because of the strong possibility that a liquid water ocean exists underneath its ice-covered surface. The primary scientific goals of the proposed Europa Lander mission are to characterize the surface material from a recent outflow and look for evidence of pre-biotic and possibly biotic chemistry. The baseline mission concept involves landing a single spacecraft on the surface of Europa with the capability to acquire samples of material, perform detailed chemical analysis of the samples, and transmit the results to Earth. This paper provides a discussion of the benefits and status of the key spacecraft and instrument technologies needed to accomplish the science objectives. Also described are variations on the baseline concept including the addition of small auxiliary probes and an experimental ice penetration probe. (copyright) 2002 Elsevier Science Ltd. All rights reserved.

EI

Aerospace Sciences; Planetary Landing; Solar System; Spacecraft

20030066242 NASA Marshall Space Flight Center, Huntsville, AL, USA

Engineering-Level Model Atmospheres for Titan & Neptune

Justus, C. G.; Johnson, D. L.; July 20, 2003; In English, 20-23 Jul. 2003, Huntsville, AL, USA

Contract(s)/Grant(s): NAS8-60000; No Copyright; Avail: CASI; A01, Hardcopy

Engineering-level atmospheric models for Titan and Neptune have been developed for use in NASA s systems analysis studies of aerocapture applications in missions to the outer planets. Analogous to highly successful Global Reference Atmospheric Models for Earth (GRAM, Justus et al., 2000) and Mars (Mars-GRAM, Justus and Johnson, 2001, Justus et al., 2002) the new models are called Titan-GRAM and Neptune-GRAM. Like GRAM and Mars-GRAM, an important feature of Titan-GRAM and Neptune-GRAM is their ability to simulate quasi-random perturbations for Monte- Carlo analyses in developing guidance, navigation and control algorithms, and for thermal systems design.

Author

Aerocapture; Titan; Monte Carlo Method; Neptune (Planet); Atmospheric Models

20030066102 Rhode Island Univ., Narragansett, RI, USA

Science and Engineering Potential of an Icy Moon Lander

DHondt, S. L.; Millerr, J. H.; Forum on Concepts and Approaches for Jupiter Icy Moons Orbiter; 2003, 17; In English; Copyright; Abstract Only; Available from CASI only as part of the entire parent document

We urge consideration of an Icy Moon Lander as part of the Jupiter Icy Moon Orbiter mission. Inclusion of a lander would have major advantages. It would allow scientific and engineering objectives to be met that cannot be addressed with an orbiter. It would also allow independent tests of surface and subsurface properties inferred from remote observations. It would provide invaluable engineering data for the design of a future ice or Ocean penetrator mission. We illustrate these advantages with

three examples. As the first example, an acoustic profiler imbedded in the surface of an icy moon could be used to identify several subsurface properties as a function of depth. Some of these properties, such as the presence and depth (or absence) of the water/ice interface and the structure and density of the ice as a function of depth, might be independently inferred by instrumentation on an orbiter. Other properties that might be determinable with an acoustic profiler cannot be imaged from orbit. These include the shear modulus of the ice (which might be used to distinguish between rigid ice and slushy convecting ice), ocean density as a function of depth, the depth of an ocean/bedrock interface, and properties of the bedrock underlying the ocean and ice. For the second example, instrumentation on a lander could undertake direct chemical analysis of organic and inorganic compounds in the surface ice and atmosphere of an icy moon. Such analyses would directly test models of surface compositions and atmospheric composition inferred from remote observations. These analyses would also greatly advance human understanding of the chemical habitability of a Jovian icy moon by directly identifying and quantifying concentrations of nutrients, energy yielding chemicals, and carbon sources in the surface ice. Thermal studies provide the third example. Lander-based thermal measurements on the surface of an icy moon would provide an absolute calibration standard for surface temperatures inferred from remote observations. Downhole temperature measurements taken at a single site with a shallow penetrator would allow modeling of the subsurface temperature profile and independent estimation of the presence and depth (or absence) of the ice/ocean interface. In closing, we wish to emphasize that inclusion of a lander with relatively low-weight instrumentation in the JIMO mission would provide a high scientific pay-off. Because the lander instrumentation would not penetrate the ice deeply, there would be no risk of directly contaminating any underlying ocean. Such a lander might require only modest adaptation of existing technology and consequently might entail relatively low cost.
Derived from text
Galilean Satellites; Satellite Surfaces; Surface Properties; Planetary Landing; Measuring Instruments; Space Probes

20030065170 NASA Langley Research Center, Hampton, VA, USA
Mars Exploration Rover Six-Degree-Of-Freedom Entry Trajectory Analysis
Desai, Prasun N.; Schoenenberger, Mark; Cheatwood, F. M.; [2003]; In English, 3-7 Aug. 2003, Big Sky, MT, USA
Report No.(s): AAS Paper 03-642; Copyright; Avail: CASI; A03, Hardcopy

The Mars Exploration Rover mission will be the next opportunity for surface exploration of Mars in January 2004. Two rovers will be delivered to the surface of Mars using the same entry, descent, and landing scenario that was developed and successfully implemented by Mars Pathfinder. This investigation describes the trajectory analysis that was performed for the hypersonic portion of the MER entry. In this analysis, a six-degree-of-freedom trajectory simulation of the entry is performed to determine the entry characteristics of the capsules. In addition, a Monte Carlo analysis is also performed to statistically assess the robustness of the entry design to off-nominal conditions to assure that all entry requirements are satisfied. The results show that the attitude at peak heating and parachute deployment are well within entry limits. In addition, the parachute deployment dynamics pressure and Mach number are also well within the design requirements.
Author
Degrees of Freedom; Trajectory Analysis; Atmospheric Entry; Mars Roving Vehicles; Mars Exploration; NASA Space Programs

20030062242 NASA Marshall Space Flight Center, Huntsville, AL, USA
NASA Development of Aerocapture Technologies
James, Bonnie; Munk, Michelle; Moon, Steve; [2003]; In English, 20-22 May 2003, Monterey, CA, USA; Copyright; Avail: CASI; A01, Hardcopy

Aeroassist technology development is a vital part of the NASA ln-Space Propulsion Program (ISP), which is managed by the NASA Headquarters Office of Space Science, and implemented by the Marshall Space Flight Center in Huntsville, Alabama. Aeroassist is the general term given to various techniques to maneuver a space vehicle within an atmosphere, using aerodynamic forces in lieu of propulsive fuel. Within the ISP, the current aeroassist technology development focus is aerocapture. The objective of the ISP Aerocapture Technology Project (ATP) is to develop technologies that can enable and/or benefit NASA science missions by significantly reducing cost, mass, and/or travel times. To accomplish this objective, the ATP identifies and prioritizes the most promising technologies using systems analysis, technology advancement and peer review, coupled with NASA Headquarters Office of Space Science target requirements. Plans are focused on developing mid-Technology Readiness Level (TRL) technologies to TRL 6 (ready for technology demonstration in space).
Author
NASA Space Programs; Aeroassist; Aerodynamic Forces; Systems Analysis; Propulsion; Aerocapture

20030055137

Development of a Monte Carlo Mars-gram model for 2001 Mars Odyssey aerobraking simulations

Dwyer, Alicia M.; Tolson, Robert H.; Munk, Michelle M.; Tartabini, Paul V.; Journal of the Astronautical Sciences; April-June 2002; ISSN 0021-9142; Volume 50, Issue no. 2, p. 191-211; In English; Copyright

Atmospheric density data taken during the Mars Global Surveyor aerobraking mission (1997-1999) showed significant variability over the altitude range (100-140 km) of interest for aerobraking. This paper presents the method by which Mars Global Surveyor data were used to determine the statistical distribution of mean density and the amplitude and phase of stationary atmospheric waves as a function of latitude. The combination of mean density and waves produced a good fit to the observed data. Using this information, a model was developed to implement the variations into Monte Carlo simulations for future missions to Mars, specifically the Mars Odyssey aerobraking mission (October, 2001-January, 2002). An example of Monte Carlo results for the Mars Odyssey aerobraking mission is shown.

EI

Atmospheric Density; Computerized Simulation; Monte Carlo Method; Planets; Space Flight

20030055136

Approaches to autonomous aerobraking at Mars

Hanna, J. L.; Tolson, R. H.; Journal of the Astronautical Sciences; April-June 2002; ISSN 0021-9142; Volume 50, Issue no. 2, p. 173-189; In English; Copyright

Planetary atmospheric aerobraking will most likely be incorporated in every future Mars orbiting mission. Aerobraking requires an intensive workload during operations. To provide safe and efficient aerobraking, both navigation and spacecraft system teams must be extremely diligent in updating spacecraft sequences and performing periapsis raise or lower maneuvers to maintain the required orbital energy reduction without exceeding the design limits of the spacecraft. Automating the process with onboard measurements could significantly reduce the operational burden and, in addition, could reduce the potential for human error. Two levels of automation are presented and validated using part of the Mars Global Surveyor aerobraking sequence and a simulated Mars Odyssey sequence. The simplest method only provides the capability to update the onboard sequence. This method uses onboard accelerometer measurements to estimate the change in orbital period during an aerobraking pass and thereby estimates the beginning of the next aerobraking sequence. Evaluation of the method utilizing MGS accelerometer data showed that the time of the next periapsis can be estimated to within 25% 3 sigma of the change in the orbital period due to drag. The second approach provides complete onboard orbit propagation. A low-order gravity model is proposed that is sufficient to provide periapsis altitude predictions to within 100-200 meters over three orbits. Accelerometer measurements are used as part of the trajectory force model while the spacecraft is in the atmosphere.

EI

Accelerometers; Navigation; Planets; Space Flight; Spacecraft

20030015758 NASA Langley Research Center, Hampton, VA USA

Wake Closure Characteristics and Afterbody Heating on a Mars Sample Return Orbiter

Horvath, Thomas J.; Cheatwood, McNeil F.; Wilmoth, Richard G.; Alter, Stephen J.; [2002]; In English, 3-7 Feb. 2002, Albuquerque, NM, USA; No Copyright; Avail: CASI; A03, Hardcopy

Aeroheating wind-tunnel tests were conducted on a 0.028 scale model of an orbiter concept considered for a possible Mars sample return mission. The primary experimental objectives were to characterize hypersonic near wake closure and determine if shear layer impingement would occur on the proposed orbiter afterbody at incidence angles necessary for a Martian aerocapture maneuver. Global heat transfer mappings, surface streamline patterns, and shock shapes were obtained in the NASA Langley 20-Inch Mach 6 Air and CF4 Tunnels for post-normal shock Reynolds numbers (based on forebody diameter) ranging from 1,400 to 415,000, angles of attack ranging from -5 to 10 degrees at 0, 3, and 6 degree sideslip, and normal-shock density ratios of 5 and 12. Laminar, transitional, and turbulent shear layer impingement on the cylindrical afterbody was inferred from the measurements and resulted in a localized heating maximum that ranged from 40 to 75 percent of the reference forebody stagnation point heating. Comparison of laminar heating prediction to experimental measurement along the orbiter afterbody highlight grid alignment challenges associated with numerical simulation of three- dimensional separated wake flows. Predicted values of a continuum breakdown parameter revealed significant regions of non-continuum flow downstream of the flow separation at the MSRO shoulder and in the region of the reattachment shock on the afterbody. The presence of these regions suggest that the Navier-Stokes predictions at the laminar wind-tunnel condition may encounter errors in the numerical calculation of the wake shear layer development and impingement due to non-continuum effects.

Author

Mars Sample Return Missions; Aerodynamic Heating; Wind Tunnel Tests; Hypersonic Wakes; Impingement; Aerocapture; Interplanetary Spacecraft; Flow Characteristics

20030014800 NASA Langley Research Center, Hampton, VA USA

Autonomous Aerobraking at Mars

Hanna, Jill L.; Tolson, Robert; Cianciolo, Alicia Dwyer; Dec, John; [2002]; In English, 22-25 Oct. 2002, Frascati, Italy; Original contains color illustrations; Copyright; Avail: CASI; A02, Hardcopy; Distribution as joint owner in the copyright

Aerobraking has become a proven approach for orbital missions at Mars. A launch of a 1000 kg class spacecraft on a Delta class booster saves 90% of the post-MOI fuel otherwise required to circularize the orbit. In 1997, Mars Global Surveyor demonstrated the feasibility and Mars 2001 Odyssey completed a nearly trouble free aerobraking phase in January 2002. In 2006, Mars Reconnaissance Orbiter will also utilize aerobraking. From the flight operations standpoint, however, aerobraking is labor intensive and high risk due to the large density variability in the Mars thermosphere. The maximum rate of aerobraking is typically limited by the maximum allowable temperature of the solar array which is the primary drag surface. Prior missions have used a surrogate variable, usually maximum free stream heat flux, as a basis for performing periapsis altitude corridor control maneuvers. This paper provides an adaptive sequential method for operationally relating measured temperatures to heat flux profile characteristics and performing maneuvers based directly on measured temperatures and atmospheric properties derived from the heat flux profiles. Simulations of autonomous aerobraking are performed using Odyssey mission data.

Author

Aerobraking; Mars Missions; Spacecraft Maneuvers; Aeromaneuvering; Flight Operations; Computerized Simulation; Temperature Profiles; Solar Arrays; Heat Flux

20030014794 NASA Langley Research Center, Hampton, VA USA

Multibody Parachute Flight Simulations for Planetary Entry Trajectories Using 'Equilibrium Points'

Raiszadeh, Ben; [2003]; In English, 9-13 Feb. 2003, Ponce, Puerto Rico; Original contains color illustrations
Report No.(s): AAS-03-163; No Copyright; Avail: CASI; A03, Hardcopy

A method has been developed to reduce numerical stiffness and computer CPU requirements of high fidelity multibody flight simulations involving parachutes for planetary entry trajectories. Typical parachute entry configurations consist of entry bodies suspended from a parachute, connected by flexible lines. To accurately calculate line forces and moments, the simulations need to keep track of the point where the flexible lines meet (confluence point). In previous multibody parachute flight simulations, the confluence point has been modeled as a point mass. Using a point mass for the confluence point tends to make the simulation numerically stiff, because its mass is typically much less that than the main rigid body masses. One solution for stiff differential equations is to use a very small integration time step. However, this results in large computer CPU requirements. In the method described in the paper, the need for using a mass as the confluence point has been eliminated. Instead, the confluence point is modeled using an 'equilibrium point'. This point is calculated at every integration step as the point at which sum of all line forces is zero (static equilibrium). The use of this 'equilibrium point' has the advantage of both reducing the numerical stiffness of the simulations, and eliminating the dynamical equations associated with vibration of a lumped mass on a high-tension string.

Author

Atmospheric Entry; Flight Simulation; Parachutes; Trajectories; Differential Equations; Computerized Simulation

20030014283 NASA Langley Research Center, Hampton, VA USA

Plume Modeling and Application to Mars 2001 Odyssey Aerobraking

Chavis, Zachary Q.; Wilmoth, Richard G.; [2002]; In English, 24-26 Jun. 2002, Saint Louis, MO, USA; Original contains color illustrations; No Copyright; Avail: CASI; A03, Hardcopy

A modified source flow model was used to calculate the plume flowfield from a Mars Odyssey thruster during aerobraking. The source flow model results compared well with previous detailed CFD results for a Mars Global Surveyor thruster. Using an iso-density surface for the Odyssey plume, DSMC simulations were performed to determine the effect the plumes have on the Odyssey aerodynamics. A database was then built to incorporate the plume effects into 6-DOF simulations over a range of attitudes and densities expected during aerobraking. 6-DOF simulations that included the plume effects showed better correlation with flight data than simulations without the plume effects.

Author

Computational Fluid Dynamics; Aerobraking; 2001 Mars Odyssey; Computerized Simulation; Rocket Exhaust; Flow Distribution; Mathematical Models

20030006687 NASA Langley Research Center, Hampton, VA USA

Thermal Analysis and Correlation of the Mars Odyssey Spacecraft's Solar Array During Aerobraking Operations

Dec, John A.; Gasbarre, Joseph F.; George, Benjamin E.; [2002]; In English, 5-8 Aug. 2002, Monterey, CA, USA; Original contains color illustrations

Report No.(s): AIAA Paper 2002-4536; Copyright; Avail: CASI; A03, Hardcopy; Distribution under U.S. Government purpose rights

The Mars Odyssey spacecraft made use of multipass aerobraking to gradually reduce its orbit period from a highly elliptical insertion orbit to its final science orbit. Aerobraking operations provided an opportunity to apply advanced thermal analysis techniques to predict the temperature of the spacecraft's solar array for each drag pass. Odyssey telemetry data was used to correlate the thermal model. The thermal analysis was tightly coupled to the flight mechanics, aerodynamics, and atmospheric modeling efforts being performed during operations. Specifically, the thermal analysis predictions required a calculation of the spacecraft's velocity relative to the atmosphere, a prediction of the atmospheric density, and a prediction of the heat transfer coefficients due to aerodynamic heating. Temperature correlations were performed by comparing predicted temperatures of the thermocouples to the actual thermocouple readings from the spacecraft. Time histories of the spacecraft relative velocity, atmospheric density, and heat transfer coefficients, calculated using flight accelerometer and quaternion data, were used to calculate the aerodynamic heating. During aerobraking operations, the correlations were used to continually update the thermal model, thus increasing confidence in the predictions. This paper describes the thermal analysis that was performed and presents the correlations to the flight data.

Author

Thermal Analysis; Correlation; 2001 Mars Odyssey; Solar Arrays; Heat Transfer Coefficients; Aerodynamic Heating

20030006120 NASA Langley Research Center, Hampton, VA USA

Control Surface and Afterbody Experimental Aeroheating for a Proposed Mars Smart Lander Aeroshell

Liechty, Derek S.; Hollis, Brian R.; Edquist, Karl T.; [2002]; In English, 5-8 Aug. 2002, Monterey, CA, USA; Original contains color illustrations

Report No.(s): AIAA Paper 2002-4506; Copyright; Avail: CASI; A03, Hardcopy; Distribution under U.S. Government purpose rights

Several configurations, having a Viking aeroshell heritage and providing lift-to-drag required for precision landing, have been considered for a proposed Mars Smart Lander. An experimental aeroheating investigation of two configurations, one having a blended tab and the other a blended shelf control surface, has been conducted at the NASA Langley Research Center in the 20-Inch Mach 6 Air Tunnel to assess heating levels on these control surfaces and their effects on afterbody heating. The proposed Mars Smart Lander concept is to be attached through its aeroshell to the main spacecraft bus, thereby producing cavities in the forebody heat shield upon separation prior to entry into the Martian atmosphere. The effects these cavities will have on the heating levels experienced by the control surface and the afterbody were also examined. The effects of Reynolds number, angle-of-attack, and cavity location on aeroheating levels and distributions were determined and are presented. At the highest angle-of-attack, blended tab heating was increased due to transitional reattachment of the separated shear layer. The placement of cavities downstream of the control surface greatly influenced aeroheating levels and distributions. Forebody heat shield cavities had no effect on afterbody heating and the presence of control surfaces decreased leeward afterbody heating slightly.

Author

Control Surfaces; Wind Tunnel Tests; Aeroshells; Aerodynamic Heating; Mars Landing

20030005808 NASA Langley Research Center, Hampton, VA USA

The Development and Evaluation of an Operational Aerobraking Strategy for the Mars 2001 Odyssey Orbiter

Tartabini, Paul V.; Munk, Michelle M.; Powell, Richard W.; [2002]; In English, 5-8 Aug. 2002, Monterey, CA, USA; Original contains color illustrations

Report No.(s): AIAA Paper 2002-4537; No Copyright; Avail: CASI; A03, Hardcopy; Distribution under U.S. Government purpose rights

The Mars 2001 Odyssey Orbiter successfully completed the aerobraking phase of its mission on January 11, 2002. This paper discusses the support provided by NASA's Langley Research Center to the navigation team at the Jet Propulsion Laboratory in the planning and operational support of Mars Odyssey Aerobraking. Specifically, the development of a three-degree-of-freedom aerobraking trajectory simulation and its application to pre-flight planning activities as well as operations is described. The importance of running the simulation in a Monte Carlo fashion to capture the effects of mission and atmospheric uncertainties is demonstrated, and the utility of including predictive logic within the simulation that could

mimic operational maneuver decision-making is shown. A description is also provided of how the simulation was adapted to support flight operations as both a validation and risk reduction tool and as a means of obtaining a statistical basis for maneuver strategy decisions. This latter application was the first use of Monte Carlo trajectory analysis in an aerobraking mission.
Author
Aerobraking; Capture Effect; Flight Operations; Navigation; Planning; Simulation; Trajectories

20030005452 NASA Johnson Space Center, Houston, TX USA
Aerocapture Guidance Algorithm Comparison Campaign
Rousseau, Stephane; Perot, Etienne; Graves, Claude; Masciarelli, James P.; Queen, Eric; [2002]; In English, 5-8 Aug. 2002, Monterey, CA, USA; Original contains color illustrations
Report No.(s): AIAA Paper 2002-4822; Copyright; Avail: CASI; A02, Hardcopy; Distribution as joint owner in the copyright

The aerocapture is a promising technique for the future human interplanetary missions. The Mars Sample Return was initially based on an insertion by aerocapture. A CNES orbiter Mars Premier was developed to demonstrate this concept. Mainly due to budget constraints, the aerocapture was cancelled for the French orbiter. A lot of studies were achieved during the three last years to develop and test different guidance algorithms (APC, EC, TPC, NPC). This work was shared between CNES and NASA, with a fruitful joint working group. To finish this study an evaluation campaign has been performed to test the different algorithms. The objective was to assess the robustness, accuracy, capability to limit the load, and the complexity of each algorithm. A simulation campaign has been specified and performed by CNES, with a similar activity on the NASA side to confirm the CNES results. This evaluation has demonstrated that the numerical guidance principal is not competitive compared to the analytical concepts. All the other algorithms are well adapted to guaranty the success of the aerocapture. The TPC appears to be the more robust, the APC the more accurate, and the EC appears to be a good compromise.
Author
Aerocapture; Spacecraft Guidance; Algorithms

20030005447 NASA Langley Research Center, Hampton, VA USA
Experimental Hypersonic Aerodynamic Characteristics of the 2001 Mars Surveyor Precision Lander with Flap
Horvath, Thomas J.; OConnell, Tod F.; Cheatwood, F. McNeil; Prabhu, Ramadas K.; Alter, Stephen J.; [2002]; In English, 5-8 Aug. 2002, Monterey, CA, USA
Report No.(s): AIAA Paper 2002-4408; Copyright; Avail: CASI; A03, Hardcopy; Distribution as joint owner in the copyright

Aerodynamic wind-tunnel screening tests were conducted on a 0.029 scale model of a proposed Mars Surveyor 2001 Precision Lander (70 deg half angle spherically blunted cone with a conical afterbody). The primary experimental objective was to determine the effectiveness of a single flap to trim the vehicle at incidence during a lifting hypersonic planetary entry. The laminar force and moment data, presented in the form of coefficients, and shock patterns from schlieren photography were obtained in the NASA Langley Aerothermodynamic Laboratory for post-normal shock Reynolds numbers (based on forebody diameter) ranging from 2,637 to 92,350, angles of attack ranging from 0 tip to 23 degrees at 0 and 2 degree sideslip, and normal-shock density ratios of 5 and 12. Based upon the proposed entry trajectory of the 2001 Lander, the blunt body heavy gas tests in CF, simulate a Mach number of approximately 12 based upon a normal shock density ratio of 12 in flight at Mars. The results from this experimental study suggest that when traditional means of providing aerodynamic trim for this class of planetary entry vehicle are not possible (e.g. offset c.g.), a single flap can provide similar aerodynamic performance. An assessment of blunt body aerodynamic effects attributed to a real gas were obtained by synergistic testing in Mach 6 ideal-air at a comparable Reynolds number. From an aerodynamic perspective, an appropriately sized flap was found to provide sufficient trim capability at the desired L/D for precision landing. Inviscid hypersonic flow computations using an unstructured grid were made to provide a quick assessment of the Lander aerodynamics. Navier-Stokes computational predictions were found to be in very good agreement with experimental measurement.
Author
Aerodynamic Characteristics; Aerothermodynamics; Hypersonic Flow; Inviscid Flow

20030002240 NASA Langley Research Center, Hampton, VA USA
Computational Analysis of Towed Ballute Interactions
Gnoffo, Peter A.; Anderson, Brian P.; [2002]; In English, 24-26 Jun. 2002, Saint Louis, MO, USA; Original contains color illustrations
Report No.(s): AIAA Paper 2002-2997; Copyright; Avail: CASI; A03, Hardcopy; Distribution as joint owner in the copyright

A ballute (balloon-parachute) is an inflatable, aerodynamic drag device for application to planetary entry vehicles. Ballutes may be directly attached to a vehicle, increasing its cross-sectional area upon inflation, or towed behind the vehicle as a semi-independent device that can be quickly cut free when the requisite change in velocity is achieved. The aerothermodynamics of spherical and toroidal towed ballutes are considered in the present study. A limiting case of zero towline length (clamped system) is also considered. A toroidal system can be designed (ignoring influence of the tethers) such that all flow processed by the bow shock of the towing spacecraft passes through the hole in the toroid. For a spherical ballute, towline length is a critical parameter that affects aeroheating on the ballute being towed through the spacecraft wake. In both cases, complex and often unsteady interactions ensue in which the spacecraft and its wake resemble an aero spike situated in front of the ballute. The strength of the interactions depends upon system geometry and Reynolds number. We show how interactions may envelope the base of the towing spacecraft or impinge on the ballute surface with adverse consequences to its thermal protection system. Geometric constraints to minimize or eliminate such adverse interactions are discussed. The towed, toroidal system and the clamped, spherical system show greatest potential for a baseline design approach.
Author
Atmospheric Entry; Ballutes; Spacecraft Control; Flight Control; Towed Bodies; Computerized Simulation

20030002226 NASA Langley Research Center, Hampton, VA USA
Application of Accelerometer Data to Mars Odyssey Aerobraking and Atmospheric Modeling
Tolson, R. H.; Keating, G. M.; George, B. E.; Escalera, P. E.; Werner, M. R.; Dwyer, A. M.; Hanna, J. L.; [2002]; In English, 5-8 Aug. 2002, Monterey, CA, USA; Original contains color illustrations
Report No.(s): AIAA Paper 2002-4533; Copyright; Avail: CASI; A03, Hardcopy; Distribution as joint owner in the copyright
Aerobraking was an enabling technology for the Mars Odyssey mission even though it involved risk due primarily to the variability of the Mars upper atmosphere. Consequently, numerous analyses based on various data types were performed during operations to reduce these risk and among these data were measurements from spacecraft accelerometers. This paper reports on the use of accelerometer data for determining atmospheric density during Odyssey aerobraking operations. Acceleration was measured along three orthogonal axes, although only data from the component along the axis nominally into the flow was used during operations. For a one second count time, the RMS noise level varied from 0.07 to 0.5 mm/s2 permitting density recovery to between 0.15 and 1.1 kg per cu km or about 2% of the mean density at periapsis during aerobraking. Accelerometer data were analyzed in near real time to provide estimates of density at periapsis, maximum density, density scale height, latitudinal gradient, longitudinal wave variations and location of the polar vortex. Summaries are given of the aerobraking phase of the mission, the accelerometer data analysis methods and operational procedures, some applications to determining thermospheric properties, and some remaining issues on interpretation of the data. Pre-flight estimates of natural variability based on Mars Global Surveyor accelerometer measurements proved reliable in the mid-latitudes, but overestimated the variability inside the polar vortex.
Author
Accelerometers; 2001 Mars Odyssey; Aerobraking; Atmospheric Models; Mars Atmosphere; Atmospheric Density; Radio Tracking; Numerical Analysis; Trajectory Analysis

20030000829 NASA Langley Research Center, Hampton, VA USA
Mars Smart Lander Parachute Simulation Model
Queen, Eric M.; Raiszadeh, Ben; [2002]; In English, 5-8 Aug. 2002, Monterey, CA, USA
Report No.(s): AIAA Paper 2002-4617; Copyright; Avail: CASI; A02, Hardcopy; Distribution under U.S. Government purpose rights
A multi-body flight simulation for the Mars Smart Lander has been developed that includes six degree-of-freedom rigid-body models for both the supersonically-deployed and subsonically-deployed parachutes. This simulation is designed to be incorporated into a larger simulation of the entire entry, descent and landing (EDL) sequence. The complete end-to-end simulation will provide attitude history predictions of all bodies throughout the flight as well as loads on each of the connecting lines. Other issues such as recontact with jettisoned elements (heat shield, back shield, parachute mortar covers, etc.), design of parachute and attachment points, and desirable line properties can also be addressed readily using this simulation.
Author
Flight Simulation; Parachutes; Mars Landing; Trajectory Analysis; Evaluation; Loads (Forces)

20030000735 CFD Research Corp., Huntsville, AL USA
CFD Prediction of the BEAGLE 2 Mars Probe Aerodynamic Database
Liever, Peter A.; Habchi, Sami D.; Burnell, Simon I.; Lingard, Steve J.; Twelfth Thermal and Fluids Analysis Workshop; July 2002; In English; Original contains color illustrations; No Copyright; Avail: CASI; A03, Hardcopy

CFD (Computational Fluid Dynamics) has matured to provide reliable planetary entry vehicle aerodynamic predictions. CFD provides substantial time and cost savings. CFD-FASTRAN was applied over the entire trajectory (Entry to Chute Deployment). It provided valuable insight into vehicle flow characteristics (Examples: Wake and Base Flow Structure, Transonic Wake Unsteadiness). A blended aerodynamic database was generated by combining CFD data, scaled existing data, and wind tunnel test data. CFD based pitch damping analysis provides insight into dynamic stability characteristics not easily obtained from wind tunnel tests.
Derived from text
Computational Fluid Dynamics; Wind Tunnel Tests; Atmospheric Entry; Predictions; Data Bases

20020081342 NASA Glenn Research Center, Cleveland, OH USA
Radioisotope Electric Propulsion for Fast Outer Planetary Orbiters
Oleson, Steven; Benson, Scott; Gefert, Leon; Patterson, Michael; Schreiber, Jeffrey; September 2002; In English, 7-10 Jul. 2002, Indianapolis, IN, USA
Contract(s)/Grant(s): RTOP 344-96-8D
Report No.(s): NASA/TM-2002-211893; NAS 1.15:211893; E-13575; AIAA Paper 2002-3967; No Copyright; Avail: CASI; A03, Hardcopy

Recent interest in outer planetary targets by the Office of Space Science has spurred the search for technology options to enable relatively quick missions to outer planetary targets. Several options are being explored including solar electric propelled stages combined with aerocapture at the target and nuclear electric propulsion. Another option uses radioisotope powered electric thrusters to reach the outer planets. Past work looked at using this technology to provide faster flybys. A better use for this technology is for outer planet orbiters. Combined with medium class launch vehicles and a new direct trajectory these small, sub-kilowatt ion thrusters and Stirling radioisotope generators were found to allow missions as fast as 5 to 12 years for objects from Saturn to Pluto, respectively. Key to the development is light spacecraft and science payload technologies.
Author
Nuclear Electric Propulsion; Radioactive Isotopes; Gas Giant Planets; Grand Tours; Aerocapture

20020077966 NASA Ames Research Center, Moffett Field, CA USA
Aerocapture Technology Development Needs for Outer Planet Exploration
Wercinski, Paul; Munk, Michelle; Powell, Richard; Hall, Jeff; Graves, Claude; Partridge, Harry, Technical Monitor; January 2002; In English
Contract(s)/Grant(s): RTOP 713-81-80
Report No.(s): NASA/TM-2002-211386; NAS 1.15:211386; A-0107378; No Copyright; Avail: CASI; A03, Hardcopy

The purpose of this white paper is to identify aerocapture technology and system level development needs to enable NASA future mission planning to support Outer Planet Exploration. Aerocapture is a flight maneuver that takes place at very high speeds within a planet's atmosphere that provides a change in velocity using aerodynamic forces (in contrast to propulsive thrust) for orbit insertion. Aerocapture is very much a system level technology where individual disciplines such as system analysis and integrated vehicle design, aerodynamics, aerothermal environments, thermal protection systems (TPS), guidance, navigation and control (GN&C) instrumentation need to be integrated and optimized to meet mission specific requirements. This paper identifies on-going activities, their relevance and potential benefit to outer planet aerocapture that include New Millennium ST7 Aerocapture concept definition study, Mars Exploration Program aeroassist project level support, and FY01 Aeroassist In-Space Guideline tasks. The challenges of performing aerocapture for outer planet missions such as Titan Explorer or Neptune Orbiter require investments to advance the technology readiness of the aerocapture technology disciplines for the unique application of outer planet aerocapture. This white paper will identify critical technology gaps (with emphasis on aeroshell concepts) and strategies for advancement.
Author
Aerocapture; Aerothermodynamics; Spacecraft Design; Orbit Insertion; Spacecraft Maneuvers; Outer Planets Explorers

20020039836 NASA Langley Research Center, Hampton, VA USA
Aerothermal Instrumentation Loads To Implement Aeroassist Technology in Future Robotic and Human Missions to MARS and Other Locations Within the Solar System
Parmar, Devendra S.; Shams, Qamar A.; April 2002; In English
Contract(s)/Grant(s): RTOP 713-81-70
Report No.(s): NASA/TM-2002-211459; NAS 1.15:211459; L-18123; No Copyright; Avail: CASI; A03, Hardcopy

The strategy of NASA to explore space objects in the vicinity of Earth and other planets of the solar system includes robotic and human missions. This strategy requires a road map for technology development that will support the robotic exploration and provide safety for the humans traveling to other celestial bodies. Aeroassist is one of the key elements of technology planning for the success of future robot and human exploration missions to other celestial bodies. Measurement of aerothermodynamic parameters such as temperature, pressure, and acceleration is of prime importance for aeroassist technology implementation and for the safety and affordability of the mission. Instrumentation and methods to measure such parameters have been reviewed in this report in view of past practices, current commercial availability of instrumentation technology, and the prospects of improvement and upgrade according to the requirements. Analysis of the usability of each identified instruments in terms of cost for efficient weight-volume ratio, power requirement, accuracy, sample rates, and other appropriate metrics such as harsh environment survivability has been reported.

Author

Aeroassist; Aerothermodynamics; Robotics; Technology Utilization; Aerodynamic Loads; Solar System; Manned Mars Missions; Temperature Measuring Instruments

20020023456 Instituto Nacional de Pesquisas Espacias, Sao Jose dos Campos, Brazil

Study of Orbital Transfers with Aeroassisted Maneuvers

Schulz, Walkiria; 2001; In Portuguese

Report No.(s): INPE-8476-TDI/776; No Copyright; Avail: CASI; A09, Hardcopy

This work presents an analysis of space missions through the development of a software package for the calculation of aerodynamic maneuvers and of the required thrust maneuvers for their implementation. Besides the numerical development, an analytical study contemplates the accomplishment of the aeroassisted phase of this maneuver type. This analysis includes a study of the thermal limits associated with a vehicle passage through the atmosphere as well as an analysis of the associated errors. Several simulations of aerodynamic maneuvers are carried out and compared with orbital changes accomplished outside of the atmosphere. Among the conclusions, it is shown that the problem is extremely sensitive to the initial conditions and each mission deserves a careful individual analysis. Finally, the results obtained from the analytical formulation are shown to be in agreement with the numerical results for the upper layers of the terrestrial atmosphere.

Author

Transfer Orbits; Space Missions; Applications Programs (Computers); Aerodynamic Characteristics; Aeroassist

20020002105 NASA Johnson Space Center, Houston, TX USA

Beagle 2: The Next Exobiology Mission to Mars

Gibson, Everett K., Jr.; Pillinger, Colin T.; Wright, Ian P.; Morse, Andy; Stewart, Jenny; Morgan, G.; Praine, Ian; Leigh, Dennis; Sims, Mark R.; General Meeting of the NASA Astrobiology Insititute; April 2001, 160-162; In English; No Copyright; Avail: Other Sources; Abstract Only

Beagle 2 is a 60 kg probe (with a 30 kg lander) developed in the UK for inclusion on the European Space Agency's 2003 Mars Express. Beagle 2 will deliver to the Martian surface a payload which consists of a high percentage of science instruments to landed spacecraft mass. Beagle 2 will be launched in June, 2003 with Mars Express on a Soyuz-Fregat rocket from the Baikonur Cosmodrome in Kazakhstan. Beagle 2 will land on Mars on December 26, 2003 in the Isidis Planitia basin (approximately 10 degrees N and 275 degrees W), a large sedimentary basin that overlies the boundary between ancient highlands and northern plains. Isidis Planitia, the third largest basin on Mars, which is possibly filled with sediment deposited at the bottom of long-standing lakes or seas, offers an ideal environment for preserving traces of life. Beagle 2 was developed to search for organic material and other volatiles on and below the surface of Mars in addition to the study of the inorganic chemistry and mineralogy. Beagle 2 will utilize a mechanical mole and grinder to obtain samples from below the surface, under rocks and inside rocks. A pair of stereo cameras will image the landing site along with a microscope for examination of surface and rock samples. Analyses will include both rock and soil samples at various wavelengths, X-ray spectrometer and Mossbauer spectrometer as well as a search for organics and other light element species (e.g. carbonates and water) and measurement of their isotopic compositions. Beagle 2 has as its focus the goal of establishing whether evidence for life existed in the past on Mars at the Isidis Planitia site or at least establishing if the conditions were ever suitable. Carbonates and organic components were first recognized as existing on Mars when they were found in the Martian meteorite Nakhla. Romanek et al showed the carbonates in ALH84001 were formed at low temperatures. McKay et al noted possible evidence of early life on Mars within the ALH84001 meteorite. Thomas-Keprta et al showed the magnetite biomarkers in ALH84001's carbonates are indistinguishable from those formed by magnetotactic bacteria found on Earth. Gibson et al showed there was significant evidence for liquid water and biogenic products present on Mars across a 3.9 billion year period. A mechanical arm (PAW) operates from the lander and is used for science operations along with sample acquisition. Instruments attached to the PAW

include: stereo cameras, Mossbauer instrument, X-ray fluorescence instrument, microscope, environmental sensors, rock corer/grinder, a spoon, mirror, brushes, a mole attachment for acquisition of subsurface to depths of 1 to 2 meters and an illumination device. Each camera has 14 filters which have been optimized for mineralogy composition, dust and water vapor detection. The microscope's camera is designed for viewing the size and shape of dust particles, rock surfaces, microfossils, and characteristics of the samples prior to introduction into the gas analysis package (GAP). The camera has a resolution of 4 microns/pixel, features four color capability (red, green, blue and UV (ultraviolet) fluoresence), a depth of focus of 40 micrometers and translation stage of +3 millimeters. The heart of the Beagle 2's life detection package is the gas analysis package (GAP), which consists of a mass spectrometer with collectors at fixed masses for precise isotopic ratio measurements and voltage scanning for spectral analysis. Primary aim of the GAP is to search for the presence of bulk constituents, individual species, and isotopic fractionations for both extinct and extent life along with studying the low-temperature geochemistry of the hydrogen, carbon, nitrogen and oxygen components on Mars from both the surface and atmosphere. GAP is a magnetic sector mass spectrometer with the range of 1 to 140 amu which can be operated in both the static and dynamic modes. A triple Faraday collector array will be used for C, N and O ratios along with a double Faraday array for H/D. Pulse counting electron multiplier will be utilized for noble gases and selected organics. Anticipated detection limits are at the picomole level for operation in the static mode of operation and high precision isotopic measurements will be made in the dynamic mode. Sample processing and preparation system consists of reaction vessels along with references. Sample ovens capable of being heated are attached to the manifold for sample combustion. Surface, subsurface materials and interior rock specimens will be combusted in pure oxygen gas at various temperature intervals to release organic matter and volatiles. Combustion process will permit detection of all forms and all atoms of carbon present in the samples. A chemical processing system is capable of a variety of conversion reactions. Gases are manipulated either by cryogenic or chemical reactions and passed through the gas handling portion of the vacuum system. There are two modes of operation: quantitative analysis and precise isotopic measurements. Additional information is contained in the original extended abstract.
Author
Exobiology; Mars Missions; Spacecraft Instruments; European Space Programs; Space Probes

20010122748 Tennessee Univ., Knoxville, TN USA
Remote Sensing of Evaporite Minerals in Badwater Basin, Death Valley, at Varying Spatial Scales and in Different Spectral Regions
Moersch, J. E.; Farmer, J.; Baldridge, A.; Field Trip and Workshop on the Martian Highlands and Mojave Desert Analogs; 2001, 45-46; In English; No Copyright; Avail: CASI; A01, Hardcopy

A key concept behind the overall architecture of NASA's Mars Surveyor Program is that remote sensing observations made from orbit will be used to guide the selection of landing sites for subsequent missions to the surface. An important component of the orbital phase of this strategy is mineralogical mapping of the surface with infrared spectrometers and imaging systems. Currently, the Mars Global Surveyor Thermal Emission Spectrometer (TES) is spectrally mapping Mars in the 6-50 micrometer region at a spatial resolution of 3 km. Starting later this year, the Thermal Emission Imaging System (THEMIS) aboard the Mars 2001 Odyssey orbiter will image the entire surface of the planet in eight broad bands in the 6.5-14.5 micrometer region at a spatial resolution of 100 m. In 2003, ESA plans to launch the OMEGA instrument on Mars Express, which will map the planet in the visible and near infrared regions from an elliptical orbit at spatial resolutions of up to 100 m. Currently, NASA is selecting a visible and near-infrared mapping spectrometer for an orbiter that will launch in 2005. This instrument will likely map at a constant spatial resolution of at least 50 m. From an astrobiological perspective, the utility of these spectral datasets will be in locating potential paleohabitats for martian life, via the detection of minerals that form in the presence of liquid water. Deposits of evaporite minerals in putative martian paleolake basins are a particularly attractive target to look for because of the areal extent of these features, the strong spectral features of these minerals, and the characteristic sequences in which they appear along the margin of a basin. Despite considerable geomorphic evidence indicating the presence of ancient lake basins on Mars, to date no evaporite deposits have been reported from the TES experiment. But is this to be expected, given the limited spatial resolution of TES data? Might we still hope to find such deposits in upcoming experiments? One way to address this question is to use existing datasets from terrestrial analog sites to attempt to determine spatial and spectral thresholds of detectability for these minerals in a natural setting
Author
Remote Sensing; Death Valley (CA); Spatial Resolution; Spectral Bands; Mineral Deposits; Structural Basins; Sedimentary Rocks

20010099686 Georgia Inst. of Tech., Atlanta, GA USA

Uncertainty Optimization Applied to the Monte Carlo Analysis of Planetary Entry Trajectories

Olds, John; Way, David; Jul. 31, 2001; In English

Contract(s)/Grant(s): NGT1-52163; No Copyright; Avail: CASI; A11, Hardcopy

Recently, strong evidence of liquid water under the surface of Mars and a meteorite that might contain ancient microbes have renewed interest in Mars exploration. With this renewed interest, NASA plans to send spacecraft to Mars approx. every 26 months. These future spacecraft will return higher-resolution images, make precision landings, engage in longer-ranging surface maneuvers, and even return Martian soil and rock samples to Earth. Future robotic missions and any human missions to Mars will require precise entries to ensure safe landings near science objective and pre-employed assets. Potential sources of water and other interesting geographic features are often located near hazards, such as within craters or along canyon walls. In order for more accurate landings to be made, spacecraft entering the Martian atmosphere need to use lift to actively control the entry. This active guidance results in much smaller landing footprints. Planning for these missions will depend heavily on Monte Carlo analysis. Monte Carlo trajectory simulations have been used with a high degree of success in recent planetary exploration missions. These analyses ascertain the impact of off-nominal conditions during a flight and account for uncertainty. Uncertainties generally stem from limitations in manufacturing tolerances, measurement capabilities, analysis accuracies, and environmental unknowns. Thousands of off-nominal trajectories are simulated by randomly dispersing uncertainty variables and collecting statistics on forecast variables. The dependability of Monte Carlo forecasts, however, is limited by the accuracy and completeness of the assumed uncertainties. This is because Monte Carlo analysis is a forward driven problem; beginning with the input uncertainties and proceeding to the forecasts outputs. It lacks a mechanism to affect or alter the uncertainties based on the forecast results. If the results are unacceptable, the current practice is to use an iterative, trial-and-error approach to reconcile discrepancies. Therefore, an improvement to the Monte Carlo analysis is needed that will allow the problem to be worked in reverse. In this way, the largest allowable dispersions that achieve the required mission objectives can be determined quantitatively.

Derived from text

Atmospheric Entry; Trajectory Optimization; Monte Carlo Method; Trajectory Planning; Trajectory Analysis; Trajectory Control; Mathematical Models

20010041296 NASA Ames Research Center, Moffett Field, CA USA

Exploration of Titan Using Vertical Lift Aerial Vehicles

Young, L. A.; Forum on Innovative Approaches to Outer Planetary Exploration 2001-2020; 2001, 94; In English; No Copyright; Abstract Only; Available from CASI only as part of the entire parent document

Autonomous vertical lift aerial vehicles (such as rotorcraft or powered-lift vehicles) hold considerable potential for supporting planetary science and exploration missions. Vertical lift aerial vehicles would have the following advantages/ attributes for planetary exploration: (1) low-speed and low-altitude detailed aerial surveys; (2) remote-site sample return to lander platforms; (3) precision placement of scientific probes; (4) soft landing capability for vehicle reuse (multiple flights) and remote-site monitoring; (5) greater range, speed, and access to hazardous terrain than a surface rover; and (6) greater resolution of surface details than an orbiter or balloons. Exploration of Titan presents an excellent opportunity for the development and usage of such vehicles. Additional information is contained in the original extended abstract.

Derived from text

Vertical Takeoff Aircraft; Space Exploration; Powered Lift Aircraft; Rotary Wing Aircraft

20010041208 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA USA

Micro Navigator

Blaes, B. R.; Kia, T.; Chau, S. N.; Forum on Innovative Approaches to Outer Planetary Exploration 2001-2020; 2001, 9; In English; No Copyright; Abstract Only; Available from CASI only as part of the entire parent document

Miniature high-performance low-mass space avionics systems are desired for planned future outer planetary exploration missions (i.e. Europa Orbiter/Lander, Pluto-Kuiper Express). The spacecraft fuel and mass requirements enabling orbit insertion is the driving requirement. The Micro Navigator is an integrated autonomous Guidance, Navigation & Control (GN&C)micro-system that would provide the critical avionics function for navigation, pointing, and precision landing. The Micro Navigator hardware and software allow fusion of data from multiple sensors to provide a single integrated vehicle state vector necessary for six degrees of freedom GN&C. The benefits of this MicroNavigator include: 1) The Micro Navigator employs MEMS devices that promise orders of magnitude reductions in mass power and volume of inertial sensors (accelerometers and gyroscopes), celestial sensing devices (startracker, sun sensor), and computing element; 2) The highly integrated nature of the unit will reduce the cost of flight missions. a) The advanced miniaturization technologies employed

by the Micro Navigator lend themselves to mass production, and therefore will reduce production cost of spacecraft. b) The integral approach simplifies interface issues associated with discrete components and reduces cost associated with integration and test of multiple components; and 3) The integration of sensors and processing elements into a single unit will allow the Micro Navigator to encapsulate attitude information and determination functions into a single object. This is particularly beneficial for object-oriented software architectures that are used in advanced spacecraft. Additional information is contained in the original extended abstract.
Derived from text
Autonomous Navigation; Miniaturization; Multisensor Fusion; Space Navigation; Spacecraft Guidance

20010038566 NASA Ames Research Center, Moffett Field, CA USA
International Agreement on Planetary Protection
Mars Sample Handling Protocol Workshop Series; October 2000, 93; In English; No Copyright; Avail: CASI; A01, Hardcopy

The maintenance of a NASA policy, is consistent with international agreements. The planetary protection policy management in OSS, with Field Center support. The advice from internal and external advisory groups (NRC, NAC/Planetary Protection Task Force). The technology research and standards development in bioload characterization. The technology research and development in bioload reduction/sterilization. This presentation focuses on: forward contamination - research on the potential for Earth life to exist on other bodies, improved strategies for planetary navigation and collision avoidance, and improved procedures for sterile spacecraft assembly, cleaning and/or sterilization; and backward contamination - development of sample transfer and container sealing technologies for Earth return, improvement in sample return landing target assessment and navigation strategy, planning for sample hazard determination requirements and procedures, safety certification, (liaison to NEO Program Office for compositional data on small bodies), facility planning for sample recovery system, quarantine, and long-term curation of 4 returned samples.
Derived from text
International Cooperation; International Law; Policies; Planetary Environments; Environment Protection

20010024974 Colorado Univ., Boulder, CO USA
Low Velocity Impact Experiments in Microgravity
Colwell, J. E.; Sture, S.; Proceedings of the Fifth Microgravity Fluid Physics and Transport Phenomena Conference; December 2000, 1335-1346; In English; No Copyright; Avail: CASI; A03, Hardcopy

Protoplanetary disks, planetary rings, the Kuiper belt, and the asteroid belt are collisionally evolved systems. Although objects in each system may be bombarded by impactors at high interplanetary velocities, they are also subject to repeated collisions at low velocities (v\h10 m/s). In some regions of Saturn's rings, for example, the typical collision velocity inferred from observations by the Voyager spacecraft and dynamical modeling is a fraction of a centimeter per second. These interparticle collisions control the rate of energy dissipation in planetary rings and the rate of accretion in the early stages of planetesimal formation. In the asteroid belt collisions typically occur at several km/s; however secondary craters are formed at much lower impact speeds. In the Kuiper belt, where orbital speeds and eccentricities are much lower, collisions between Kuiper belt objects (KBOs) can occur at speeds below 100 m/s. In the early solar system, KBOs accreted in the same way planetesimals accreted in the inner solar system, however some regions of the Kuiper belt may now undergo erosional collisions. Dust may be present on the surface of all of these objects in the form of a fine regolith created from micrometeoroid bombardment (rings, asteroids, KBOs), high speed interparticle collisions (asteroids, KBOs) or as a product of accretion from protoplanetary dust. Dust released in these collisions is often the only observable trace of the source objects and may be used to infer the physical properties of those larger bodies. We are conducting a broad program of microgravity impact experiments into dust to study the dissipation of energy in low energy collisions and the production of dust ejecta in these impacts. The Collisions Into Dust Experiment (COLLIDE) flew on STS-90 in April 1998. The principal results of that experiment were measurements of the coefficient of restitution for impacts into powders at impact speeds below 1 m/s. Almost no ejecta was produced in impacts at 15 cm/s into JSC-1 powder, and the coefficient of restitution was about 0.03. COLLIDE-2 is undergoing final preparations for a flight in 2001. The experiment will conduct six impact experiments at impact speeds between 1 and 100 cm/s. The target material will have a low relative density to mimic the regolith on low surface gravity objects in space, such as planetesimals, planetary ring particles, and asteroids. A new experimental program, the Physics of Regolith Impacts in Microgravity Experiment (PRIME) will use NASA's KC-135 aircraft to explore a much broader range of parameter space than is possible with COLLIDE, at slightly higher impact velocities. PRIME will be capable of conducting up to 16 impact experiments each flight day on the KC-135. Impact velocities between 50 cm/s and 5 m/s will be studied into a variety of target materials and size distributions. The experiment will consist of an evacuated canister with 6 to 8 impact chambers on each of two rotating turntables. Each impact chamber will include a target sample and a launcher with a unique set of parameters.

Two viewports will allow high speed video photography of impacts from two orthogonal views with the use of a mirror mounted inside the canister. Data from COLLIDE and ground-based experimental studies suggest that particle size distribution is an important parameter in controlling the response of granular media to low velocity impacts. Individual grain shapes may also play an important role in the conversion of impactor kinetic energy to target grain kinetic energy. We will also make use of numerical simulations of the impact process to understand the relevant parameters for experimental study. High speed video of the impact and ejecta patterns will be analyzed to determine the ejecta mass and velocity distributions. This in turn will have direct application for understanding the behavior of dust on the surfaces of planetary objects including asteroids and small moons when disturbed by low velocity impacts and perturbations. These include naturally occurring impacts as well as disturbances to the surface from human and spacecraft activity. The velocity distribution of the ejecta determines the amount of material launched to various altitudes above the surface and escaping the parent body. This information is important for spacecraft instruments landing on airless bodies with low surface gravity and powdery regoliths.
Author (revised)
Collisions; Dust; Gravitational Effects; Low Speed; Microgravity; Impact; Energy Dissipation

20010023145 Centre National d'Etudes Spatiales, France
The Stakes of the Aerocapture for Missions to Mars
Cledassou, R.; Lam-Trong, Th.; Charbonnier, J. M.; Concepts and Approaches for Mars Exploration; July 2000, Issue Part 1, 186; In English; No Copyright; Abstract Only; Available from CASI only as part of the entire parent document

The Hohmann transfer trajectory is an economical way to go from Earth to Mars but a spacecraft has to reduce its speed very significantly upon arrival in order to be inserted into a Mars orbit. The aerocapture is a way to do that, by using the Martian atmosphere to produce sufficient aerodynamic drag force on a heatshield and achieve the required deceleration. This presentation will address the major stake of the aerocapture which is twofold: a) We will list the different technologies and areas of knowledge related to the aerocapture, identify the risks associated with each of them and finally demonstrate that aerocapture is not as risky as it is said to be; b) Aerocapture saves a huge amount of propellant and so allows to improve dramatically the dollar/kg ratio for any payload at Mars by using this mass savings for payloads and by decreasing the launch cost. This benefit is particularly evident for a return mission because of the amplification factor of the propellant mass for the escape of Mars ('snow ball' effect). We will have a quantitative analysis of some typical cases of spacecraft vs. launcher performance . We will conclude that aerocapture is interesting for the present robotic missions and certainly a good investment for the future manned missions to Mars.
Derived from text
Mars Missions; Aerocapture; Earth-Mars Trajectories; Transfer Orbits

20010023141 Science Applications International Corp., Littleton, CO USA
Precision Terminal Guidance for a Mars Lander
Klarquist, William N.; Wahl, Beth E.; Lowrie, James W.; Concepts and Approaches for Mars Exploration; July 2000, Issue Part 1, 178-179; In English; No Copyright; Avail: CASI; A01, Hardcopy

To date Mars landers have relied solely on Earth-based navigation measurements to achieve a desired landing site. They've had no active guidance and control system to monitor and control the entry and descent trajectory or guide the final landing. This results in very large landing site uncertainties (\g180 km x 20 km) and precludes targeting specific, small scale regions such as canyons and flood channels. Moreover, localized hazards cannot be sensed or avoided, resulting in higher mission risk. SAIC's Center for Intelligent Systems, (SAIC-CIS) based on current and past research, believes that reliably accurate landings at pre-selected sites are achievable and that the mission risk associated with local hazards can be greatly reduced. Our concept involves applying an integrated system level solution that leverages the tremendous amount of information available on the Martian environment and applies modern technologies in the areas of visual based navigation, maneuverable parachutes, and advanced sensors.
Derived from text
Active Control; Terminal Guidance; Spacecraft Guidance; Mars Landing

20010023136 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA USA
Mars Sample Return without Landing on the Surface
Jurewicz, A. J. G.; Jones, Steven M.; Yen, A. S.; Concepts and Approaches for Mars Exploration; July 2000, Issue Part 1, 168-169; In English; No Copyright; Avail: CASI; A01, Hardcopy

Many in the science community want a Mars sample return in the near future, with the expectation that it will provide

in-depth information, significantly beyond what we know from remote sensing, limited in-situ measurements, and work with Martian meteorites. Certainly, return of samples from the Moon resulted in major advances in our understanding of both the geologic history of our planetary satellite, and its relationship to Earth. Similar scientific insights would be expected from analyses of samples returned from Mars. Unfortunately, Mars-lander sample-return missions have been delayed, for the reason that NASA needs more time to review the complexities and risks associated with that type of mission. A traditional sample return entails a complex transfer-chain, including landing, collection, launch, rendezvous, and the return to Earth, as well as an evaluation of potential biological hazards involved with bringing pristine Martian organics to Earth. There are, however, means of returning scientifically-rich samples from Mars without landing on the surface. This paper discusses an approach for returning intact samples of surface dust, based on known instrument technology, without using an actual Martian lander.
Derived from text
Mars Sample Return Missions; Particulate Sampling; Aerocapture

20010020516 Arizona Univ., Tucson, AZ USA
The Martian Oasis Detector
Smith, P. H.; tomasko, M. G.; McEwen, A.; Rice, J.; Concepts and Approaches for Mars Exploration; July 2000, Issue Part 2, 286-287; In English; No Copyright; Avail: CASI; A01, Hardcopy

The next phase of unmanned Mars missions paves the way for astronauts to land on the surface of Mars. There are lessons to be learned from the unmanned precursor missions to the Moon and the Apollo lunar surface expeditions. These unmanned missions (Ranger, Lunar Orbiter, and Surveyor) provided the following valuable information, useful from both a scientific and engineering perspective, which was required to prepare the way for the manned exploration of the lunar surface: (1) high resolution imagery instrumental to Apollo landing site selection also tremendously advanced the state of Nearside and Farside regional geology; (2) demonstrated precision landing (less than two kilometers from target) and soft landing capability; (3) established that the surface had sufficient bearing strength to support a spacecraft; and (4) examination of the chemical composition and mechanical properties of the surface. The search for extinct or extant life on Mars will follow the water. However, geomorphic studies have shown that Mars has had liquid water on its surface throughout its geologic history. A cornucopia of potential landing sites with water histories (lakes, floodplains, oceans, deltas, hydrothermal regions) presently exist. How will we narrow down site selection and increase the likelihood of finding the signs of life? One way to do this is to identify ‘Martian oases.’ It is known that the Martian surface is often highly fractured and some areas have karst structures that support underground caves. Much of the water that formed the channels and valley networks is thought to be frozen underground. All that is needed to create the potential for liquid water is a near surface source of heat; recent lava flows and Martian meteorites attest to the potential for volcanic activity. If we can locate even one spot where fracturing, ice, and underground heat are co-located then we have the potential for an oasis. Such a discovery could truly excite the imaginations of both the public and Congress providing an attainable goal for both robotic and manned missions. The instrument required to detect an active oasis is a high spatial resolution (few tens of meters) Short Wavelength Infrared (SWIR) spectrometer coupled with a high resolution camera (five m/pixel). This combination creates too large a data volume to possibly return data for the entire Martian Surface; therefore it has been designed as one of the first in a new generation of ‘smart’ detectors, called the Mars Oasis Detector (MOD).
Author
Mars (Planet); Water; Mars Missions; Mars Surface; Spacecraft Instruments; Oases; Mars Exploration

20010020495 California Univ., Los Angeles, CA USA
After the Mars Polar Lander: Where to Next?
Paige, D. A.; Boynton, W. V.; Crisp, D.; DeJong, E.; Hansen, C. J.; Harri, A. M.; Keller, H. U.; Leshin, L. A.; May, R. D.; Smith, P. H., et al.; Concepts and Approaches for Mars Exploration; July 2000, Issue Part 2, 245-246; In English; No Copyright; Avail: CASI; A01, Hardcopy

The recent loss of the Mars Polar Lander (MPL) mission represents a serious setback to Mars science and exploration. Targeted to land on the Martian south polar layered deposits at 76 degrees south latitude and 195 degrees west longitude, it would have been the first mission to study the geology, atmospheric environment, and volatiles at a high-latitude landing site. Since the conception of the MPL mission, a Mars exploration strategy has emerged which focuses on Climate, Resources and Life, with the behavior and history of water as the unifying theme. A successful MPL mission would have made significant contributions towards these goals, particularly in understanding the distribution and behavior of near-surface water, and the nature and climate history of the south polar layered deposits. Unfortunately, due to concerns regarding the design of the MPL spacecraft, the rarity of direct trajectories that enable high-latitude landings, and funding, an exact reflight of MPL is not feasible within the present planning horizon. However, there remains significant interest in recapturing the scientific goals of

the MPL mission. The following is a discussion of scientific and strategic issues relevant to planning the next polar lander mission, and beyond.
Author
Mars Exploration; Mission Planning; Mars Missions; Polar Regions; Mars (Planet)

20010020467 Science Applications International Corp., Littleton, CO USA
Precision Navigation for a Mars Airplane
Lowrie, James W.; Concepts and Approaches for Mars Exploration; July 2000, Issue Part 2, 196-197; In English; No Copyright; Avail: CASI; A01, Hardcopy

The rough Martian terrain significantly impedes high speed travel by wheeled vehicles and much of it is simply inaccessible given the capability of typical rover designs. Airplanes, however, have much greater range and can provide access to scientifically interesting terrain that is inaccessible to landers and rovers. Moreover, they can provide coverage of a large portion of the surface and return high resolution images and science data not practical from orbiting spacecraft. Precise navigation on Earth requires a constellation of satellites such as GPS (Global Positioning Satellites) or a network of precisely located and calibrated ground beacons, an approach that is impractical for Mars exploration in the near future. In order to realize the benefits of airplane exploration on Mars, a precision navigation system is required. Such a system also provides a high degree of autonomous capability because it enables: (1) Accurate overflight of specifically targeted sites. (2) Hazard avoidance in low altitude flight. (3) The collection of 'focused' science data which reduces overall data volume and supports an optimized data return strategy (4) Accurate spatial and temporal correlation of acquired science data with orbiter observations. (5) A geodetically referenced site survey capability. (6) A soft landing capability by providing in-flight landing site selection and terminal guidance. (7) Return to a base station following flight. (8) Precise placement of science probes and future navigation beacons. SAIC's Center for Intelligent Systems (SAIC-CIS) leverages on experience from unmanned vehicle research to propose a concept for an intelligent landmark navigation system that relies on autonomous real-time recognition of visible surface features during flight.
Author
Mars Missions; Mars Exploration; Mars (Planet); Autonomous Navigation; Aircraft

20010019289 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA USA
MOLA-Based Landing Site Characterization
Duxbury, T. C.; Ivanov, A. B.; First Landing Site Workshop for the 2003 Mars Exploration Rovers; 2001, 18-19; In English; No Copyright; Abstract Only; Available from CASI only as part of the entire parent document

The Mars Global Surveyor (MGS) Mars Orbiter Laser Altimeter (MOLA) data provide the basis for site characterization and selection never before possible. The basic MOLA information includes absolute radii, elevation and 1 micrometer albedo with derived datasets including digital image models (DIM's illuminated elevation data), slopes maps and slope statistics and small scale surface roughness maps and statistics. These quantities are useful in downsizing potential sites from descent engineering constraints and landing/roving hazard and mobility assessments. Slope baselines at the few hundred meter level and surface roughness at the 10 meter level are possible. Additionally, the MOLA-derived Mars surface offers the possibility to precisely register and map project other instrument datasets (images, ultraviolet, infrared, radar, etc.) taken at different resolution, viewing and lighting geometry, building multiple layers of an information cube for site characterization and selection. Examples of direct MOLA data, data derived from MOLA and other instruments data registered to MOLA arc given for the Hematite area.
Author
Mars Global Surveyor; Mars Surface; Landing Sites; Laser Altimeters

20010002491 California Univ., Los Angeles, CA USA
After the Mars Polar Lander: Where to Next?
Paige, D. A.; International Conference on Mars Polar Science and Exploration; August 2000, 140-141; In English; No Copyright; Avail: CASI; A01, Hardcopy

The recent loss of the Mars Polar Lander (MPL) mission represents a serious setback to Mars science and exploration. Targeted to land on the Martian south polar layered deposits at 76 deg south latitude and 195 deg west longitude, it would have been the first mission to study the geology, atmospheric environment, and volatiles at a high-latitude landing site. Since the conception of the MPL mission, a Mars exploration strategy has emerged which focuses on Climate, Resources and Life, with the behavior and history of water as the unifying theme. A successful MPL mission would have made significant

contributions towards these goals, particularly in understanding the distribution and behavior of near-surface water, and the nature and climate history of the south polar layered deposits. Unfortunately, due to concerns regarding the design of the MPL spacecraft, the rarity of direct trajectories that enable high-latitude landings, and funding, an exact reflight of MPL is not feasible within the present planning horizon. However, there remains significant interest in recapturing the scientific goals of the MPL mission. The following is a discussion of scientific and strategic issues relevant to planning the next polar lander mission, and beyond. Additional information is contained in the original extended abstract.
Author
Mars (Planet); Mars Exploration; Mars Polar Lander; Polar Regions; Mars Missions

20000102372 Tennessee Univ., Knoxville, TN USA
Earth Return Aerocapture for the TransHab/Ellipsled Vehicle
Muth, W. D.; Hoffmann, C.; Lyne, J. E.; October 2000; In English
Contract(s)/Grant(s): NAG1-2163; No Copyright; Avail: CASI; A04, Hardcopy

The current architecture being considered by NASA for a human Mars mission involves the use of an aerocapture procedure at Mars arrival and possibly upon Earth return. This technique would be used to decelerate the vehicles and insert them into their desired target orbits, thereby eliminating the need for propulsive orbital insertions. The crew may make the interplanetary journey in a large, inflatable habitat known as the TransHab. It has been proposed that upon Earth return, this habitat be captured into orbit for use on subsequent missions. In this case, the TransHab would be complimented with an aeroshell, which would protect it from heating during the atmospheric entry and provide the vehicle with aerodynamic lift. The aeroshell has been dubbed the 'Ellipsled' because of its characteristic shape. This paper reports the results of a preliminary study of the aerocapture of the TransHab/Ellipsled vehicle upon Earth return. Undershoot and overshoot boundaries have been determined for a range of entry velocities, and the effects of variations in the atmospheric density profile, the vehicle deceleration limit, the maximum vehicle roll rate, the target orbit, and the vehicle ballistic coefficient have been examined. A simple, 180 degree roll maneuver was implemented in the undershoot trajectories to target the desired 407 km circular Earth orbit. A three-roll sequence was developed to target not only a specific orbital energy, but also a particular inclination, thereby decreasing propulsive inclination changes and post-aerocapture delta-V requirements. Results show that the TransHab/Ellipsled vehicle has a nominal corridor width of at least 0.7 degrees for entry speeds up to 14.0 km/s. Most trajectories were simulated using continuum flow aerodynamics, but the impact of high-altitude viscous effects was evaluated and found to be minimal. In addition, entry corridor comparisons have been made between the TransHab/Ellipsled and a modified Apollo capsule which is also being considered as the crew return vehicle; because of its slightly higher lift-to-drag ratio, the TransHab has a modest advantage with regard to corridor width. Stagnation-point heating rates and integrated heat loads were determined for a range of vehicle ballistic coefficients and entry velocities.
Author
Spacecraft Design; Product Development; Aerocapture; Aeromaneuvering; Interplanetary Transfer Orbits; Atmospheric Entry

20000085950 North Carolina State Univ., Raleigh, NC USA
An Investigation of Terminal Guidance and Control Techniques for a Robotic Mars Lander
Birge, Brian K.; Walberg, Gerald; [2000]; In English
Contract(s)/Grant(s): NAG1-2222; No Copyright; Avail: CASI; A03, Hardcopy

Continuing on previous work, various precision landing control algorithms arc examined with the goal of minimizing the landed distance to a specified location on the Mars surface. This study considers a set of points from parachute handoff to touchdown on the surface. The first scenario considers a reverse gravity turn to a hover condition 500 meters above the surface and then uses lateral thrusting to minimize die range to target. The second scenario examines a guided, lifting parachute followed by a powered gravity turn to the targeted landing site. The third scenario considers thrust vectoring while on the ballistic parachute, followed by a reverse gravity turn to touchdown.
Author
Terminal Guidance; Command Guidance; Control Systems Design; Thrust Vector Control; Control Theory

20000074639 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA USA
The Deep Space 4/Champollion Comet Rendezvous and Lander Technology Demonstration Mission
Smythe, William D.; Weissman, Paul R.; Muirhead, Brian K.; Tan-Wang, Grace H.; Sabahi, Dara; Grimes, James M.; [2000]; In English; No Copyright; Avail: Other Sources; Abstract Only

The Deep Space 4/Champollion mission is designed to test and validate technologies for landing on and anchoring to small bodies, and sample collection and transfer, in preparation for future sample return missions from comets, asteroids, and satellites. in addition, DS-4 will test technologies for advanced, multi-engine solar electric propulsion (SEP) systems, inflatable-rigidizable solar arrays, autonomous navigation and precision guidance for landing, autonomous hazard detection and avoidance, and advanced integrated avionics and packaging concepts. Deep Space-4/Champollion consists of two spacecraft: an orbiter/carrier vehicle which includes the multi-engine SEP stage, and a lander, called Champollion, which will descend to the surface of the 46P/Tempel 1 cometary nucleus. The spacecraft will launch in April, 2003 and land on the comet in September, 2006 Deep Space 4/Champollion is a joint project between NASA and CNES, the French space agency.
Author
Deep Space; Space Missions; Mission Planning; Landing; Comets; Asteroids

20000074247 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA USA
Navigation Strategy for the Mars 2001 Lander Mission
Mase, Robert A.; Spencer, David A.; Smith, John C.; Braun, Robert D.; [2000]; In English; No Copyright; Avail: Other Sources; Abstract Only

The Mars Surveyor Program (MSP) is an ongoing series of missions designed to robotically study, map and search for signs of life on the planet Mars. The MSP 2001 project will advance the effort by sending an orbiter, a lander and a rover to the red planet in the 2001 opportunity. Each vehicle will carry a science payload that will Investigate the Martian environment on both a global and on a local scale. Although this mission will not directly search for signs of life, or cache samples to be returned to Earth, it will demonstrate certain enabling technologies that will be utilized by the future Mars Sample Return missions. One technology that is needed for the Sample Return mission is the capability to place a vehicle on the surface within several kilometers of the targeted landing site. The MSP'01 Lander will take the first major step towards this type of precision landing at Mars. Significant reduction of the landed footprint will be achieved through two technology advances. The first, and most dramatic, is hypersonic aeromaneuvering; the second is improved approach navigation. As a result, the guided entry will produce in a footprint that is only tens of kilometers, which is an order of magnitude improvement over the Pathfinder and Mars Polar Lander ballistic entries. This reduction will significantly enhance scientific return by enabling the potential selection of otherwise unreachable landing sites with unique geologic interest and public appeal. A landed footprint reduction from hundreds to tens of kilometers is also a milestone on the path towards human exploration of Mars, where the desire is to place multiple vehicles within several hundred meters of the planned landing site. Hypersonic aeromaneuvering is an extension of the atmospheric flight goals of the previous landed missions, Pathfinder and Mars Polar Lander (MPL), that utilizes aerodynamic lift and an autonomous guidance algorithm while in the upper atmosphere. The onboard guidance algorithm will control the direction of the lift vector, via bank angle modulation, to keep the vehicle on the desired trajectory. While numerous autonomous guidance algorithms have been developed for use during hypersonic flight at Earth, this will be the first flight of an autonomously directed lifting entry vehicle at Mars. However, without sufficient control and knowledge of the atmospheric entry conditions, the guidance algorithm will not perform effectively. The goal of the interplanetary navigation strategy is to deliver the spacecraft to the desired entry condition with sufficient accuracy and knowledge to enable satisfactory guidance algorithm performance. Specifically, the entry flight path angle must not exceed 0.27 deg. to a 3 sigma confidence level. Entry errors will contribute directly to the size of the landed footprint and the most significant component is entry flight path angle. The size of the entry corridor is limited on the shallow side by integrated heating constraints, and on the steep side by deceleration (g-load) and terminal descent propellant. In order to meet this tight constraint it is necessary to place a targeting maneuver seven hours prior to the time of entry. At this time the trajectory knowledge will be quite accurate, and the effects of maneuver execution errors will be small. The drawback is that entry accuracy is dependent on the success of this final late maneuver. Because propulsive maneuvers are critical events, it is desirable to minimize their occurrence and provide the flight team with as much response time as possible in the event of a spacecraft fault. A mission critical maneuver at Entry - 7 hours does not provide much fault tolerance, and it is desirable to provide a strategy that minimizes reliance on this maneuver. This paper will focus on the Improvements in interplanetary navigation that will decrease entry errors and will reduce the landed footprint, even in the absence of aeromaneuvering. The easiest to take advantage of are Improvements In the knowledge of the Mars ephemeris and gravity field due to the MGS and MSP'98 missions. Improvements In data collection and reduction techniques such as 'precislon ranging' and near-simultaneous tracking will also be utilized. In addition to precise trajectory control, a robust strategy for communications and flight operations must also be demonstrated. The result Is a navigation and communications strategy on approach that utilizes optimal maneuver placement to take advantage of trajectory knowledge, minimizes risk for the flight operations team, is responsive to spacecraft hardware limitations, and achieves the entry corridor. The MSP2001 mission Is managed at JPL under the auspices of the Mars

Exploration Directorate. The spacecraft flight elements are built and managed by Lockheed-Martin Astronautics in Denver, Colorado.
Author
Interplanetary Navigation; Landing Sites; Mars Landing; Earth-Mars Trajectories; Orbital Mechanics; Orbit Calculation; Mars Surveyor 2001 Mission

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A Light-Weight Inflatable Hypersonic Drag Device for Planetary Entry
McRonald, Angus D.; [2000]; In English; No Copyright; Avail: Other Sources; Abstract Only

The author has analyzed the use of a light-weight inflatable hypersonic drag device, called a ballute, for flight in planetary atmospheres, for entry, aerocapture, and aerobraking. Studies to date include Mars, Venus, Earth, Saturn, Titan, Neptune and Pluto, and data on a Pluto lander and a Mars orbiter will be presented to illustrate the concept. The main advantage of using a ballute is that aero, deceleration and heating in atmospheric entry occurs at much smaller atmospheric density with a ballute than without it. For example, if a ballute has a diameter 10 times as large as the spacecraft, for unchanged total mass, entry speed and entry angle,the atmospheric density at peak convective heating is reduced by a factor of 100, reducing the heating by a factor of 10 for the spacecraft and a factor of 30 for the ballute. Consequently the entry payload (lander, orbiter, etc) is subject to much less heating, requires a much reduced thermal. protection system (possibly only an MLI blanket), and the spacecraft design is therefore relatively unchanged from its vacuum counterpart. The heat flux on the ballute is small enough to be radiated at temperatures below 800 K or so. Also, the heating may be reduced further because the ballute enters at a more shallow angle, even allowing for the increased delivery angle error. Added advantages are less mass ratio of entry system to total entry mass, and freedom from the low-density and transonic instability problems that conventional rigid entry bodies suffer, since the vehicle attitude is determined by the ballute, usually released at continuum conditions (hypersonic for an orbiter, and subsonic for a lander). Also, for a lander the range from entry to touchdown is less, offering a smaller footprint. The ballute derives an entry corridor for aerocapture by entering on a path that would lead to landing, and releasing the ballute adaptively, responding to measured deceleration, at a speed computed to achieve the desired orbiter exit conditions. For a lander an accurate landing point could be achieved by providing the lander with a small gliding capacity, using the large potential energy available from being subsonic at high altitude. Alternatively the ballute can be retained to act as a parachute or soft-landing device, or to float the payload as a buoyant aerobot. As expected, the ballute has smaller size for relatively small entry speeds, such as for Mars and Titan, or for the extensive atmosphere of a low-gravity planet such as Pluto. Details of a ballute to place a small Mars orbiter and a small Pluto lander will be given to illustrate the concept. The author will discuss presently available ballute materials and a development program of aerodynamic tests and materials that would be required for ballutes to achieve their full potential.
Author
Aerodynamic Heating; Research; Ballutes; Buoyancy; Drag Devices; Floats; Inflatable Structures; Microgravity; Planetary Atmospheres; Spacecraft Design

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Precise Image-Based Motion Estimation for Autonomous Small Body Exploration
Johnson, Andrew Edie; Matthies, Larry H.; [2000]; In English; 5th; No Copyright; Avail: CASI; A01, Hardcopy

We have developed and tested a software algorithm that enables onboard autonomous motion estimation near small bodies using descent camera imagery and laser altimetry. Through simulation and testing, we have shown that visual feature tracking can decrease uncertainty in spacecraft motion to a level that makes landing on small, irregularly shaped, bodies feasible. Possible future work will include qualification of the algorithm as a flight experiment for the Deep Space 4/Champollion comet lander mission currently under study at the Jet Propulsion Laboratory.
Author
Estimating; Autonomy; Spacecraft Motion; Optical Tracking; Image Analysis; Algorithms

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Aerobraking at Venus and Mars: A Comparison of the Magellan and Mars Global Surveyor Aerobraking Phases
Lyons, Daniel T.; [2000]; In English; No Copyright; Avail: CASI; A01, Hardcopy

On February 4, 1999 the Mars Global Surveyor spacecraft became the second spacecraft to successfully aerobrake into a nearly circular orbit about another planet. This paper will highlight some of the similarities and differences between the aerobraking phases of this mission and the first mission to use aerobraking, the Magellan mission to Venus. Although the Mars

Global Surveyor (MGS) spacecraft was designed for aerobraking and the Magellan spacecraft was not, aerobraking MGS was a much more challenging task than aerobraking Magellan, primarily because the spacecraft was damaged during the initial deployment of the solar panels. The MGS aerobraking phase had to be completely redesigned to minimize the bending moment acting on a broken yoke connecting one of the solar panels to the spacecraft. Even if the MGS spacecraft was undamaged, aerobraking at Mars was more challenging than aerobraking at Venus for several reasons. First, Mars is subject to dust storms, which can significantly change the temperature of the atmosphere due to increased solar heating in the low and middle altitudes (below 50 km), which in turn can significantly increase the density at the aerobraking altitudes (above 100 km). During the first part of the MGS aerobraking phase, a regional dust storm was observed to have a significant and very rapid effect on the entire atmosphere of Mars. Computer simulations of global dust storms on Mars indicate that even larger density increases are possible than those observed during the MGS aerobraking phases. For many aerobraking missions, the duration of the aerobraking phase must be kept as short as possible to minimize the total mission cost. For Mars missions, a short aerobraking phase means that there will be less margin to accommodate atmospheric variability, so the operations team must be ready to propulsively raise periapsis by tens of kilometers on very short notice. This issue was less of a concern on Venus, where the thick lower atmosphere and the slow planet rotation resulted in more predictable atmospheric densities from one orbit to the next.
Author
Aerobraking; Mars Global Surveyor; Magellan Spacecraft (NASA); Circular Orbits

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The Strategy for the Second Phase of Aerobraking Mars Global Surveyor
Johnston, M. D.; Esposito, P. B.; Alwar, V.; Demcak, S. W.; Graat, E. J.; Burkhart, P. D.; Portock, B. M.; [2000]; In English; No Copyright; Avail: CASI; A01, Hardcopy

On February 19, 1999, the Mars Global Surveyor (MGS) spacecraft was able to propulsively establish its mapping orbit. This event followed the completion of the second phase of aerobraking for the MGS spacecraft on February 4, 1999. For the first time, a spacecraft at Mars had successfully employed aerobraking methods in order to reach its desired pre-launch mapping orbit. This was accomplished despite a damaged spacecraft solar array. The MGS spacecraft was launched on November 7, 1996, and after a ten month interplanetary transit was inserted into a highly elliptical capture orbit at Mars on September 12, 1997. Unlike other interplanetary missions, the MGS spacecraft was launched with a planned mission delta-V ((Delta)V) deficit of nearly 1250 m/s. To overcome this AV deficit, aerobraking techniques were employed. However, damage discovered to one of the spacecraft's two solar arrays after launch forced major revisions to the original aerobraking planning of the MGS mission. In order to avoid a complete structural failure of the array, peak dynamic pressure levels for the spacecraft were established at a major spacecraft health review in November 1997. These peak dynamic pressure levels were roughly one-third of the original mission design values. Incorporating the new dynamic pressure limitations into mission replanning efforts resulted in an 'extended' orbit insertion phase for the mission. This 'extended' orbit insertion phase was characterized by two distinct periods of aerobraking separated by an aerobraking hiatus that would last for several months in an intermediate orbit called the 'Science Phasing Orbit' (SPO). This paper describes and focuses on the strategy for the second phase of aerobraking for the MGS mission called 'Aerobraking Phase 2.' This description will include the baseline aerobraking flight profile, the trajectory control methodology, as well as the key trajectory metrics that were monitored in order to successfully 'guide' the spacecraft to its desired mapping orbit. Additionally, the actual aerobraking progress is contrasted to the planned aerobraking flight profile. (A separate paper will describe the navigation aspects of MGS aerobraking in detail.) Key to the success of the MGS mission is the delivery of the spacecraft to its final mapping orbit and the synergy the instrument complement provides to its scientific investigators when science data is returned from that orbit. The MGS mapping orbit is characterized as a low altitude, near-circular, near-polar orbit that is Sun-synchronous with the descending equatorial crossing at 2:00 AM local mean solar time (LMST).
Derived from text
Aerobraking; Mars Global Surveyor; Mapping; Orbit Insertion; Trajectory Control; Navigation; Mission Planning

Subject Terms

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